VOLUME 4 NUMBER 3

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CONTENTS OF PREVIOUS NUMBERS

NOVEMBER, 1921. NUMBER 3

The Pathology of Chronic Cystic Mastitis of the Female Breast: with Special Consideration of the Blue-Domed Cyst. Joseph Colt Bloodgood, M.D., Baltimore.

The Achievements and Limitations of Neurologic Surgery. Charles H. Frazier, M.D., Philadelphia.

A Review of a Year's Series of Intracranial Tumors: June, 1920, to June, 1921. Charles Edward Locke, Jr., M.D., Boston.

Postoperative Biliary Fistulas. Donald C. Balfour, M.D., and James W. Ross, M.B. (Tor.), Rochester, Minn.

The Suspension Traction Treatment of Fractures of the Long Bones Near Large Joints. John A. Hartwell, M.D., New York.

The Relation of Surgical Technic to Gastrojejunal Ulcer. C. A. Roeder, M.D., Omaha.

A Method of Determining the Early Regeneration of Nerve Fibers at Operation. Julian Y. Malone, M.D., St. Louis.

Intestinal Obstruction. Donald K. Bacon, M.D.; Robert E. Anslow, M.D., and Hazel H. Eppler, Detroit.

JANUARY, 1922. NUMBER 1

Studies in Experimental Traumatic Shock: IV. Evidence of a Toxic Factor in Wound Shock. W. B. Cannon, M.D., Boston.

Further Observations on the Lymphatic Origin of Cholecystitis, Choledochitis and the Associated Pancreatitis. Evarts A. Graham, M.D., and M. G. Peterman, M.D., St. Louis.

Classification and Mechanism of Fractures of the Leg Bones Involving the Ankle, Based on a Study of Three Hundred Cases from the Episcopal Hospital. Astley P. C. Ashhurst, M.D., and Ralph S. Bromer, M.D., Philadelphia.

Studies in Exhaustion. III. Emotion. G. W. Crile, M.D., Cleveland.

Structural Results of Prostatectomy with Reference to Methods of Enucleation, Based on a Study of One Hundred and Thirty-Six Cases. Frank Hinman, M.D., San Francisco.

Relaxed Pelvic Floor: End-Results in Sixty Cases. Elliott C. Cutler, M.D., and C. Harold Jameson, M.D., Boston.

Sixteenth Report of Progress in Orthopedic Surgery. Robert B. Osgood, M.D.; Robert Soutter, M.D.; Harry C. Low, M.D.; Murray S. Danforth, M.D.; C. Hermann Bucholz, M.D.; Lloyd T. Brown, M.D., and Philip D. Wilson, M.D., Boston.

MARCH, 1922. NUMBER 2

Ventriculocordectomy: A New Operation for the Cure of Goitrous Paralytic Laryngeal Stenosis. Chevalier Jackson, M.D., Philadelphia.

Papilloma of the Larynx in Children: A Report of Eleven Cases. S. J. Crowe, M.D., and M. L. Breitstein, M.D., Baltimore.

Studies in Experimental Traumatic Shock: V. The Critical Level in a Falling Blood Pressure. W. B. Cannon, M.D., and McKeen Cattell, Ph.D., Boston.

Postoperative Intra-Abdominal Hernia. C. H. Mayo, M.D., and J. A. H. Magoun, Jr., M.D., Rochester, Minn.

The Radical Cure of Tuberculosis of the Seminal Tract: I. Brief Survey of the Literature. H. H. Young, M.D., Baltimore.

Radiohumeral Bursitis, Epicondylitis, Epicondylalgia (Tennis Elbow): A Personal Experience. R. B. Osgood, M.D., Boston.

Studies in Traumatic Fractures of the Cranial Bones: I. Edema of the Brain; II. Bruises of the Brain. C. W. Apfelbach, S.B., Chicago.

Technic of the Treatment of Carcinoma of the Bladder and Prostate by a Combination of Surgery, Electrocoagulation, Radium Implantation and Roentgen Ray. B. A. Thomas, M.D., and G. E. Pfahler, M.D., Philadelphia.

A Detailed Bacteriologic Study of a Case of Gas Gangrene Following a Compound Fracture: Studies on Pathogenic Anaerobes. III. Clinical Observations by E. L. Barney, M.D., Bacteriologic Studies by H. H. Heller, Ph.D., San Francisco.

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ARCHIVES OF SURGERY

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A REVIEW AND CLASSIFICATION OF BONE SARCOMAS

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NEW YORK

The knowledge of tumors of bone and bone marrow is still in the descriptive stage. To reach a correct histologic diagnosis of the case and to provide some conception of the probable clinical course are all that can be expected at the present time, and often more than is accomplished. The separation of the numerous tumors of this group into well-defined clinical and pathologic entities is far from complete, while knowledge of the exact origins of these tumors and of their various exciting and contributing causative factors is extremely fragmentary, or, indeed, wholly lacking. Moreover, with the present trend of medical research, the prospects are not favorable to important progress in this field. Serology, immunology, chemistry, studies in nutrition, and the use of modern instruments of precision have contributed little and promise little in the study of bone tumors. Abundant clinical material, wide clinical experience, and knowledge of the embryology, physiology and pathology of bone, are the more essential qualifications for successful investigation in this field.

Such studies call for clinical observation by the surgeon, and morphologic research by the pathologist, by each of whom the work must be carried out on a broad and systematic plan. The surgeon must provide complete clinical pictures of the different neoplastic diseases of bone; and the pathologist must discover the origin, the predisposing anatomic conditions, the mode of growth, and the general etiologic factors, if an effective knowledge of these diseases is to be attained. When this knowledge has been secured, it will still be necessary to devise means for its dissemination so that it may become effective in controlling the mortality and possibly the incidence of these diseases.

For this purpose a uniform nomenclature is highly desirable or essential; and the main clinical and morphologic features of the different bone tumors must be clearly presented in accessible form. The present article is intended as a contribution toward this end.

CLASSIFICATION OF TUMORS OF BONE AND BONE MARROW

In the legitimate classification of tumors of bone only those neoplastic diseases which clinical experience shows to actually occur must be

recognized. To divide the tissues into their constituent cells and to classify tumors blindly according to the possible cells of origin is unsound and unserviceable. Most tumors are not simple structures composed of a single cell, but are complex and become simple growths only in anaplastic metastases. Moreover, the tumors do not develop at random. They arise under quite definite conditions, which usually determine their course, and these conditions must be considered in a classification. The classification must be both clinical and anatomic. If a central chondrosarcoma arises from an aberrant superfluous island of cartilage misplaced by a rachitic process, then this disease may be recognized as a specific entity. If an osteogenic sarcoma arises at an epiphyseal line from traumatic partial separation of the epiphysis, or because of some structural defect, it also becomes a specific entity which deserves to appear in classification. On the other hand, if in the foregoing examples, considerable variations in structure of the tumors are observed in different cases which run much the same clinical course, it is unwarranted to subdivide such tumors because of minor structural variations, since they remain essentially the same diseases in origin, course, and general significance. The practice of designating bone tumors simply as round, spindle, or giant cell is quite inadequate to define the disease properly. Nearly all malignant tumors show all these types of cells at different periods or in different portions. When, however, the disease has been identified, for example, as osteogenic sarcoma, the further designation of cell type (spindle, etc.), is useful to indicate the degree of anaplasia or potential malignancy of the tumor. To a considerable extent, it is possible to classify bone tumors according to the foregoing plan, while increasing knowledge will serve to correct errors as they come to light. Only such a classification will be of service to both clinician and pathologist. Accordingly, one may recognize the forms of neoplastic diseases originating in bone and bone marrow given in the accompanying classification.

Classification of Bone Tumors

- Osteoma
  - Spongy
  - Ivory
- Chondroma
  - Pure chondroma
  - Chrondromyxoma
  - Myxoma
  - Capsular
  - Periosteal
  - Central
- Angioma: Cavernous
- Endothelioma
  - Angio-endothelioma
  - Diffuse
  - Solitary
  - Multiple
- Benign Central Giant Cell Tumor and Its Variants
  1. Bone cyst
  2. Giant cell tumor
  3. Xanthosarcoma
  4. Myxosarcoma (benign)

Osteogenic Sarcoma
- Periosteal (extraperiosteal)
- Solid medullary and subperiosteal
- Telangiectatic
- Sclerosing

Myeloma
- Plasma cell
- Lymphocytic
- Myelocytic
- Erythroblastic

The inclusion of pure myxoma under the heading chondroma appears to be indicated because of the great probability that all pure myxomas of bone are derived originally from cartilage. The myxomas may be more difficult to eradicate surgically than chondromas but they do not exhibit any greater potential malignancy. Under the benign giant cell tumors, which must usually be regarded as sequelae of osteitis fibrosa cystica, are included for convenience sake, simple bone cysts. These lesions are not tumors; but Martland has shown that the simple cyst may result from the spontaneous degeneration and softening of a giant cell tumor.

The existence of telangiectatic osteogenic sarcoma as a distinct disease has not yet gained general acceptance. However, I am convinced that this lesion is one of the most specific of bone tumors, both in its gross anatomy and in its clinical course. One type of malignant bone aneurysm is a vascular osteogenic sarcoma. Its possible relation to cavernous angioma must be considered. In spite of recent contributions to the contrary I believe that the existence of four specific types of myeloma is firmly established. Wallgren,[1] however, concludes that all myelomas arise from a single primitive marrow cell. Of the groups of tumors mentioned above, I shall discuss only the cellular forms in the present paper.

Outline of the Clinical, Anatomic and Structural Features of Some Common Bone Tumors

ENDOTHELIOMA

The knowledge of endothelioma of bone has reached a stage which calls for definite recognition of this disease. The condition is generally submerged under the general diagnosis of round cell sarcoma or myeloma, since both are composed of small diffusely growing cells with round nuclei. Having seen ten cases within the past year, I cannot regard it as a rare disease. Three anatomic forms may be recognized: (1) multiple endothelioma; (2) solitary angio-endothelioma, and (3) diffuse endothelioma.

1. Multiple endothelioma, in which nearly every bone in the body was the seat of small medullary tumors, occurred in a remarkable

1. Wallgren: Virchows Arch. f. path. Anat. **232**:331, 1921.

case described by Marckwald. It is the only recorded case of its kind. Symmers and Vance [2] have described a somewhat similar case, and multiple tumors in much smaller numbers have often been observed. In several of the cases collected by Howard and Crile, there were

Fig. 1.—Angio-endothelioma of bone.

multiple tumors. Whether the several tumors were primary or secondary and metastatic from one original growth cannot be determined; but multiple primary tumors undoubtedly occur. They appear in adults

2. Symmers, D., and Vance, M.: Am. J. M. Sc. **152**:28 (July) 1916.

and nearly all have been fatal. Metastases in lungs and lymph nodes occur. It does not appear that any have been treated by modern roentgen-ray technic. The diagnosis rests on the roentgenogram, which shows multiple central tumors with diffuse absorption of bone. Multiple myelomas are much more numerous and sharply perforate the bone. The structure consists of endothelial-like cells in small groups or sheets, often forming alveoli and sometimes cysts containing serous or mucinous fluid.

Wells has recently described a multiple endothelioma in which isolated small groups of cells, similar to those described by Marckwald, appeared, which seemed to be derived from the blood vessels of atrophic and mucinous bone marrow.

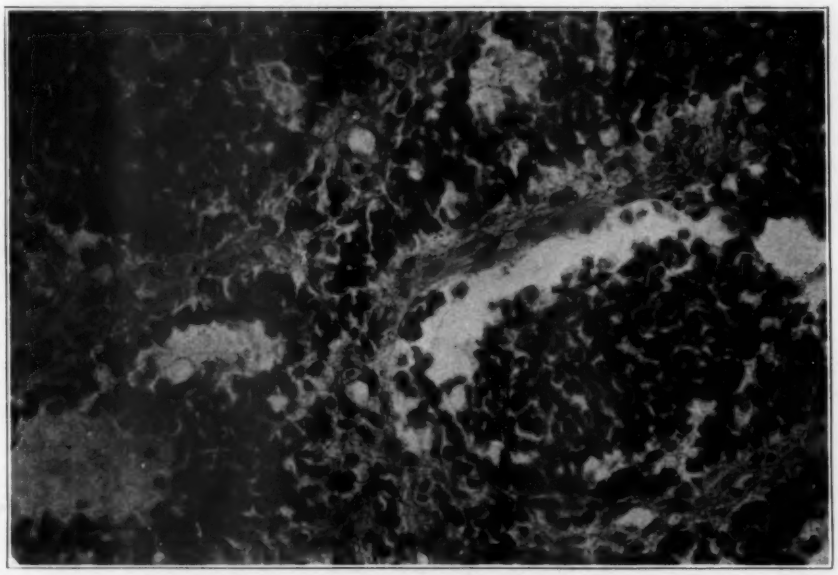

Fig. 2.—Structure of angio-endothelioma of bone.

2. Angio-endothelioma usually appears as a single tumor which sharply and completely destroys the bone and often reaches large dimensions (Fig. 1). Its expansile pulsation places it among the malignant bone aneurysms. The roentgen ray shows a clean cut destruction of bone by a central tumor which displaces and eventually invades the soft parts. There is no bony capsule and the periosteum is free. This disease returns after amputation and produces metastases. It grows much more rapidly than the benign central giant cell tumor, but can hardly be distinguished from telangiectatic sarcoma on clinical and roentgen-ray evidence. From the ordinary osteogenic sarcoma it differs in that it fails to show a wide zone of involved periosteum extending beyond the main tumor mass. These differences are rendered obvious by a comparison of the photographs of gross specimens with roentgen-

ograms. The structure is highly characteristic, consisting of large clear endothelial cells in cords and columns inclosing circulating blood (Fig. 2). The subjects are chiefly adults.

3. Solitary diffuse endothelioma occurs in young subjects, all of my patients being under 21 years of age, five of them being 14 years old. The bones involved were: ulna, twice; radius, once; tibia, twice; scapula, once; skull, once; pubes, twice, and femur, once. It begins slowly, with pain and gradually developing disability. After several months, spontaneous fracture may occur. Transient variations in size of the tumor have been noted and may prove very deceptive both to the patient and to the physician. One patient died from metastases after amputation. Another developed multiple tumors of the skull. Bence-Jones protein was found in one case only. The tumors develop in the marrow or in the bone or in both. The shaft is widened and slowly absorbed without a trace of bone production. The soft tissues are gradually invaded. The most striking feature, best revealed by the roentgen ray, is the involvement of a large segment or the whole of the shaft, which distinguishes the process from osteogenic sarcoma and the giant cell tumor. This location, together with the smooth fading of a slightly widened shaft, generally permits a diagnosis from the roentgenogram alone (Fig. 3). The differential diagnosis from the benign giant cell tumor and from osteogenic sarcoma is assured if the tumor recedes rapidly under roentgen-ray or radium treatment. True myelomas, however, may respond in the same manner. The structure presents diffuse sheets of small polyhedral cells with clear cytoplasm, without intervening stroma, often undergoing mucoid or hydropic degeneration (Fig. 4). Zenker's solution best preserves the cell form. After poor fixation, the tissue resembles that of a myeloma or "round cell sarcoma." That the cells are endothelial is shown by the appearance in some cases of many spaces lined by tumor cells and filled with intact blood. The structure may approach that of angio-endothelioma or it may verge on myeloma. Plasma cells are absent or scanty and uncertain; but the possible relation of this tumor to plasma cell myeloma remains to be determined.

The importance of recognizing this tumor lies in the fact that amputation is probably unnecessary, because the tissue is remarkably susceptible to the roentgen ray and radium. The prognosis is, however, complicated by the occurrence of multiple tumors and metastases. One of my patients died with multiple tumors of the skull which were believed to be primary, and another is said to have died with pulmonary metastases after amputation of the arm.

The comparative frequency of this disease renders it one of the most important of bone tumors. Since the structure is quite different

Fig. 3.—Diffuse endothelioma of ulna.

from that of the easily recognized endotheliomas with blood channels, alveoli and cystic spaces, it appears clear that the cases are not recognized as endothelioma, but are classed as round cell sarcoma or myeloma. Since solitary myeloma is not a frequent diagnosis, most of the cases probably pass as round cell sarcoma. Unless the pathologist is familiar with the structural details of diffuse endothelioma, he will invariably render a diagnosis of round, or possibly small, spindle cell sarcoma, or myeloma, in these cases. I have been making this error myself for many years, although I was long aware that the tumors did not correspond to any known form of bone cell or bone marrow cell neoplasm. That the tumors are not osteogenic sarcoma became apparent when their prompt recession under radium was

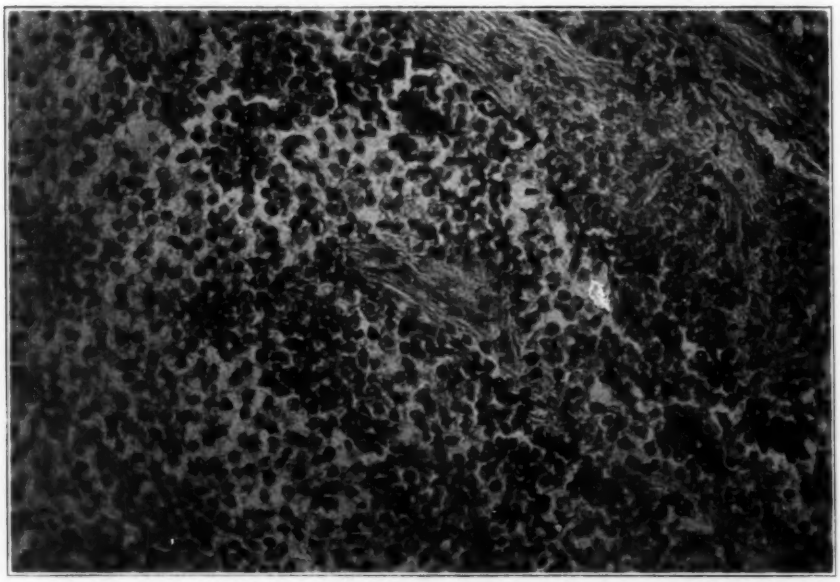

Fig. 4.—Diffuse endothelioma of bone; showing compact structure of large polyhedral cells.

observed, for oseogenic sarcoma reacts slowly to radium. That the growths are of endothelial nature was strongly suggested by the appearance of broad sheets of clear polyhedral cells without a trace of intercellular stroma. This origin was finally demonstrated by the observation of a case in which the usual diffuse structure was present in much of the material removed at exploratory operation, while in other portions the growth was composed exclusively of blood spaces filled with intact blood and lined by large clear endothelial cells.

The apparent limitation of the disease to young patients is one of its most interesting and suggestive features. Of the twenty cases of

endothelioma collected by Howard and Crile,[3] three occurred in patients under 20 years of age. One of these in the femur of a girl of 9 years, with other tumors in the skull, approached in structure the diffuse type, the blood spaces being lined by from five to ten rows of cells. In Kolaczek's patient, 18 years of age, a very large tumor of the tibia was in part composed of spindle cells, and in part of alveolar endothelioma. Crile's patient, at 11 years, showed alveoli and well defined lymph spaces. As Crile points out, the angio-endotheliomas occur with few exceptions after the period (40 years) when osteogenic sarcoma is most frequent. They often develop in patients of quite advanced years, 50 to 75, when osteogenic sarcoma is practically unknown.

These observations regarding age incidence throw no light on the nature of the underlying conditions in the bone and marrow which lead to endothelioma; but they show that endothelioma yields somewhat different results at different periods of life.

Much further exploration of the dark territory of the general pathology of bone and bone marrow is needed before one can formulate any hypothesis regarding the conditions of origin of these tumors. Most of the young subjects show a secondary anemia, without specific characters. Usually the skeleton is delicately built. A history of rickets or scurvy or other notable disorders of childhood has not been elicited. Six of my ten patients were Jews. One was very fat, as were also his two brothers. Signs of status lymphaticus were not definitely present.

Regarding the choice of treatment of this disease, I wish to emphasize the caution, that, while the diffuse endotheliomas of young subjects have proved uniformly susceptible to heavy radium packs and to repeated applications of roentgen ray, sufficient time has not elapsed to determine the final outcome of this treatment. The tumors tend to recur unless treatment is continued over a long period. The danger of metastases during treatment must be considered. On the other hand, the tendency to produce metastases appears to be less prominent than in the case of osteogenic sarcoma. Many of the multiple tumors are probably primary, so that amputation is often futile. Hence it seems justifiable or even strongly indicated to immobilize the member and attempt to save the limb or life by physical therapy. If this plan is adopted, it is highly important to avoid incision into the tumor. The diagnosis can generally be made on the clinical history, the peculiar roentgenogram, and the early response to radium. It may be of interest to note that competent observers firmly maintained that some of my cases were osteomyelitis, while one patient was persistently treated with arsphenamin.

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3. Howard and Crile: Ann. Surg. **42**:358, 1905.

BENIGN GIANT CELL TUMOR AND ITS VARIANTS

In 1852, Nelaton and Robin, in a well illustrated monograph, clearly pointed out the gross, microscopic and clinical features of this benign *tumeur à myeloplacques,* contrasted it with the malignant osteogenic sarcoma, and urged conservative treatment. Gross, also, in 1868, clearly described the disease and recognized its benign nature. These contributions seem not to have been widely read; but several later writers, especially in America, have described the disease and discussed it as an important novelty. It is quite apparent also that many surgeons and pathologists are still unfamiliar with the important differences that separate this disease from osteogenic sarcoma, so that many limbs have been unnecessarily sacrificed and many supposed bone sarcomas have been erroneously assumed to be operative cures.

The knowledge of the clinical and morphologic characters of the common benign central giant cell tumor we owe chiefly to Nelaton and Robin; but it has long been felt that the scope of these tumors is inadequately defined. Some of them do not behave like benign neoplasms. Gross believed that he observed violations of the rule that they never produce metastases. Many of them recur after operation and infiltrate the soft tissue or even break into the joints. Also the microscopic diagnosis occasionally presents serious difficulties, even for the experienced observer. It is the variants of the disease which give rise to difficulty.

The typical forms of the disease seem to find their origin mainly in the changes produced by osteitis fibrosa cystica; and the simple bone cyst is usually found as a part of localized osteitis fibrosa. Osteitis fibrosa affects one or many bones and produces a change in the marrow marked by diffuse overgrowth of spindle cells, loss of hematoblastic and fat cells, absorption of cancellous tissue and often thinning of the shafts. About the dissolving bone trabeculae and along the inner surface of the shaft, numerous giant cells are often found. Cysts form in the new tissue, and these may be lined by giant cells and filled with serous fluid. Hemorrhages readily occur in the cysts and the inflammatory reaction about these blood masses leads to the growth of granulation tissue in which are often many giant cells and disintegrating bone. In some such manner the ordinary giant cell tumor probably develops; but it must be admitted that the exact mode of origin of the simple tumors has never been certainly traced. Martland [4] has shown that simple cysts may result from the liquefaction of previous giant cell tumors. I have evidence that some giant cell tumors result from the absorption of aberrant islands of cartilage with neoplastic proliferation of the released cartilage cells, and others. It appears

4. Martland, H. S.: Proc. New York Path. Soc. **21**:102, 1921.

Fig. 5.—Benign central giant cell sarcoma, epulis type; showing limiting shell of bone and multicystic appearance.

also that any simple hematoma of bone marrow may lead to the production of granulation tissue with many giant cells. Barrie's designation "hemorrhagic osteomyelitis" would not be inept for some of these processes if it did not suggest an intense inflammatory reaction. This array of possible initiatives of the peculiar tumor tissue is not inconsistent with the variety of clinical conditions under which the disease is observed. The benign giant cell tumor is of wide occurrence as respects age, location, multiplicity, and previous history of the patient, and it is unlikely that it always arises under identical conditions.

1. *Typical Benign Central Giant Cell Tumor.*—This is a characteristic condition. It occurs usually as a single tumor in one end of the tibia, fibula, humerus, femur, lower jaw, or lower end of the radius, or in the flat bones. It progresses slowly, with pain, swelling and disability. Spontaneous fracture may result. The soft parts are displaced. It usually begins near the epiphyseal line, where the cancellous tissue is absorbed and the shaft widened by a globular mass. A thin, sometimes crackling, shell of bone is regularly laid down about the advancing tumor.

The roentgenogram shows a multicystic appearance, with destruction of the shaft, an irregular deposit of outlying shell of bone and sharp limitation from the soft tissues. Occurring in the middle of a long bone, there may be a sharp irregular fracture with comparatively little widening. Beyond the tumor the periosteum is unaffected (Figs. 5 and 6).

On gross examination such tumors are nearly always found to be cystic; or the central portion is diffluent and filled with blood detritus, chocolate colored fluid, or clear serum. The texture of the growth is that of soft, reddish, vascular granulation tissue, becoming more and more dense toward the periphery.

The structure shows an abundance of giant cells with many small separate nuclei. They appear in masses or they surround capillaries or blood spaces. They are derived from the vascular endothelium but participate in the tumor process, sometimes extensively. The stroma is composed of many capillaries supported by a moderate number of spindle fibroblasts with nuclei showing normal or slightly increased chromatin (Fig. 7). Tumors of this type are always strictly benign, in the oncologic sense, although they may lead to serious clinical disturbances. They may be cured by curettage, by roentgen ray and radium, and some of them disappear spontaneously. They may become transformed into simple cysts. They are prone to become infected from curettage or exploratory incision, and a progressive cellulitis and osteomyelitis may develop. The wide cavities left after curettage may offer some surgical problems.

Fig. 6.—Benign giant cell tumor of upper end of tibia; collapse of joint surface without invasion of joint cavity; infection through line of diagnostic incision.

2. *Xanthosarcoma.*—Some of the central giant cell tumors of bone are solid throughout, firm, dry, and yellow. The yellow color is due to the presence of many large polyhedral cells distended with lipoid granules. This is a structure commonly designated as xanthoma (Fig. 8). These tumors have greater growth capacity than the ordinary giant cell tumor. They often reach considerable size, breaking down the bony capsule and forcing their way between muscle and fasciae, but definite infiltrative growth is rare. They may destroy the epiphysis and lead to collapse of the joint surface. The roentgenogram reveals an incomplete bony capsule, or none.

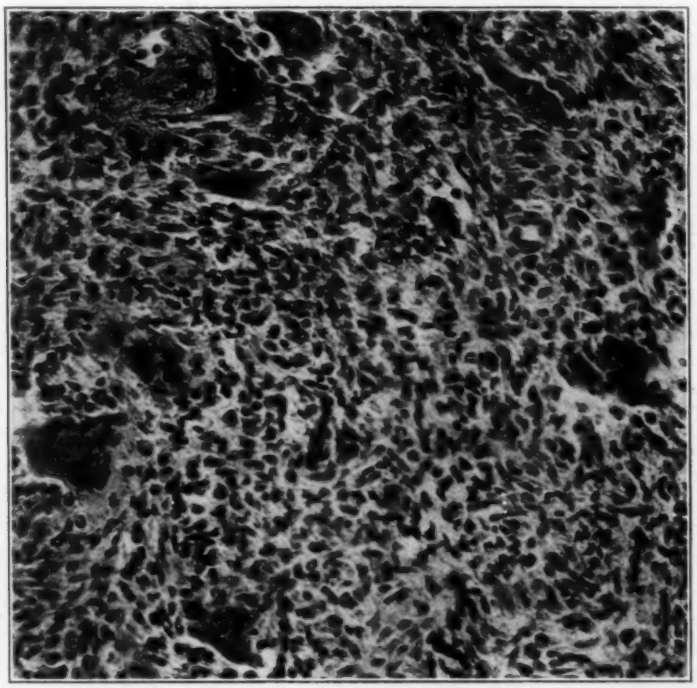

Fig. 7.—Structure of benign giant cell tumor; polynuclear giant cells lying among spindle and polyhedral cells; slight hyperchromatism of nuclei.

The structure presents a diffuse growth of medium sized spindle cells with very little hyperchromatism. Varying proportions of the tissue are composed of the lipoid cells. Giant cells are missing over large portions of the growth; but usually they appear abundantly in some portions, generally about blood spaces or blood extravasations. If the histologist encounters only the spindle cells, an erroneous impression of a malignant tumor is liable to be gained.

These tumors are prone to recur after curettage, especially when large, owing to the difficulty of reaching all portions of the growth.

Infection is also a frequent complication which results in the loss of many limbs and of some lives. They slowly respond to roentgen-ray and radium treatment; but one who chooses this method of treatment must plan to restrict the motion of the part and devote some months to the treatment. Immobilization reduces blood supply, avoids the danger of fracture, and permits weakened joint surfaces to remain intact.

I have never known these tumors to produce metastases, and I have been unable to find authentic records of such complication; but it seems quite possible that by curettage groups of viable cells could be dislodged from the tumor and pass into the blood vessels. However,

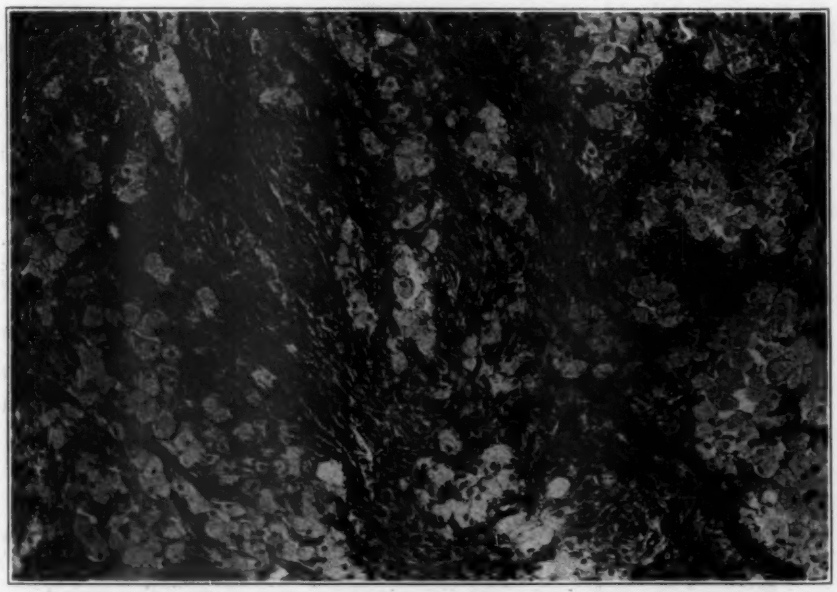

Fig. 8.—Benign giant cell tumor; peripheral portions showing xanthosarcoma; other portions showed many typical giant cells of epulis type.

the blood vessels are usually small and scanty, and the danger of metastases can probably be ignored.

That the central xanthosarcoma of bone is a variant of the giant cell tumor is clearly indicated by the clinical history, central location, general structure, the course of the growth as revealed by the roentgen ray, and by the not infrequent occurrence of xanthoma cells in typical giant cell tumors. In the benign tumors of tendon sheaths xanthoma cells are generally prominent.

3. *Myxosarcoma.*—The peripheral portions of many giant cell tumors are often composed of solid elastic opaque tumor tissue of myxoma-

like structure, while the central area alone is soft and vascular and contains the characteristic giant cells. Even this central area may be reduced to a minimum, and nearly the whole tumor may be composed of solid opaque tumor tissue in which there are many spindle cells lying in a mucinous matrix (Fig. 9). Although the central location and rather sharp limitation of the growth strongly indicate a benign character, the histologic structure with many spindle cells suggests malignancy, and this impression may be strengthened by reliance on frozen sections. However, these central tumors are benign and their

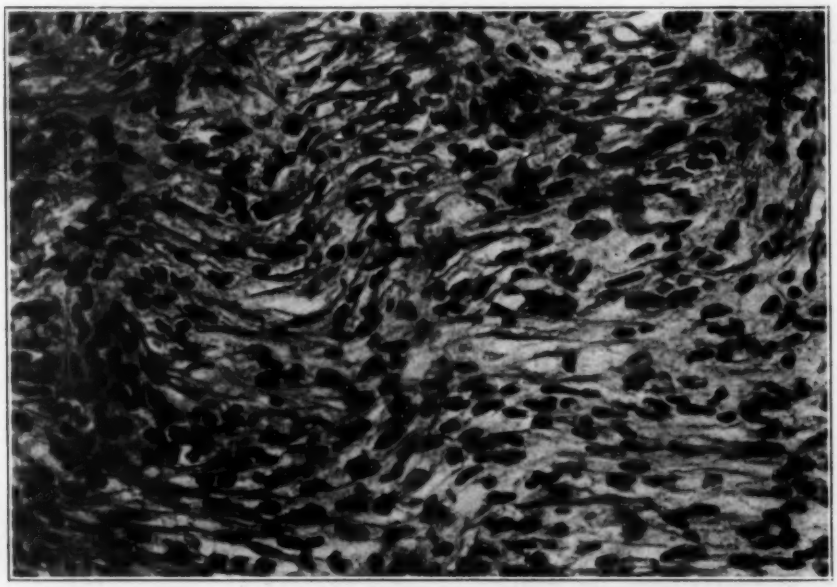

Fig. 9.—Benign giant cell tumor; peripheral portions composed of large spindle cells with clear cytoplasm; other portions showed giant cells of epulis type.

virtual identity with the ordinary giant cell tumor is shown by the gross transitional forms which connect the two types and by the presence of typical giant cells which may be seen in some parts of the tumor. They are quite different in structure from the fascial myxosarcomas and from any myxomatous areas of osteogenic sarcoma.

In some cases the main tumor cell is large and spindle or polyhedral in form with vesicular nucleus, while giant cells are scanty. These spindle cells lack the hyperchromatism of the malignant osteogenic tumors. Numerous small lymphocytes may also appear diffusely or in clusters, which are probably derived from the lymphoid marrow and which are almost never seen in malignant sarcomas (Fig. 10).

4. *Giant Cell Tumors of Cartilaginous Origin.*—Occasionally, one encounters giant cell tumors containing islands, streaks, or larger masses of hyaline cartilage. Since there are no indications that the giant cell tumor can produce cartilage, one is forced to conclude that the tumor is associated with the absorption of misplaced islands of cartilage. Such misplaced masses of cartilage lying in the marrow cavity in the vicinity of the epiphyseal line are very frequently seen in rickets. All the tumors of this type that I have seen were found at the ends of long bones.

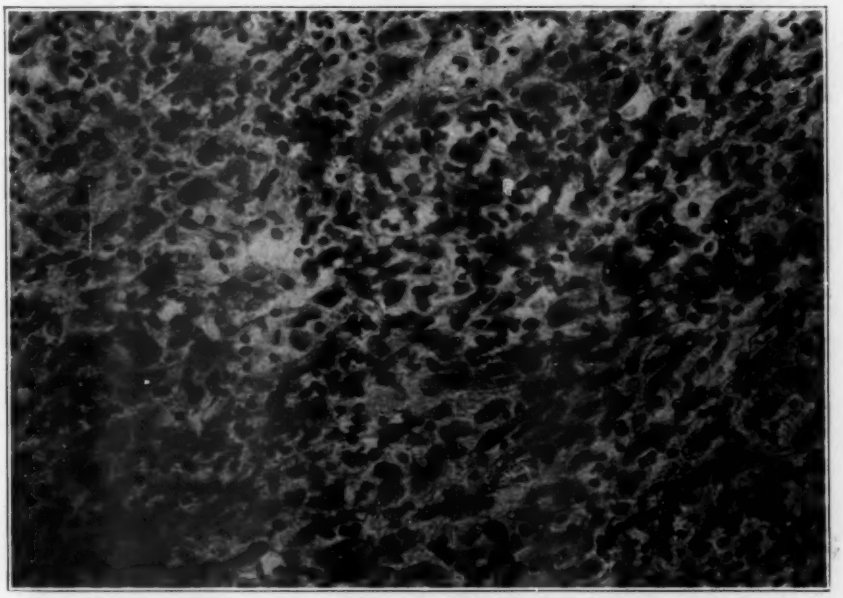

Fig. 10.—Benign giant cell tumor, edematous and infiltrated with lympocytes; tissue composed of polyhedral cells with clear cytoplasm; giant cells of epulis type in other portions of tumor.

They are of rather solid texture, opaque, sometimes slightly mucinous, and lack the reddish jelly-like features or the yellow color of the other forms. The giant cells are generally numerous and of the usual character. They lie among many smaller tumor cells which are often round or polyhedral, while the vascular spindle cell tissue of the ordinary giant cell tumor is missing. These round cells may grow diffusely over considerable areas in which giant cells are scanty or missing, so that the diagnosis of myeloma may be returned if only a small portion of the tissue is available for examination. Hence, as with many other bone tumors, a biopsy is a somewhat hazardous resort (Fig. 11).

It seems probable that these growths represent a vigorous proliferation of tissue cells about degenerating cartilage. Probably the cartilage cells participate in this process as well as the endothelial and possibly other marrow cells. That the absorption of cartilage may be connected with other giant cell tumors in which no traces of cartilage or their peculiar derivatives are present, deserves, perhaps, further consideration. From their cellular character, one gains the impression that these tumors must be more malignant than the others; but several patients whom I have followed recovered after curettage. Being cellular they should be susceptible to radium and roentgen ray.

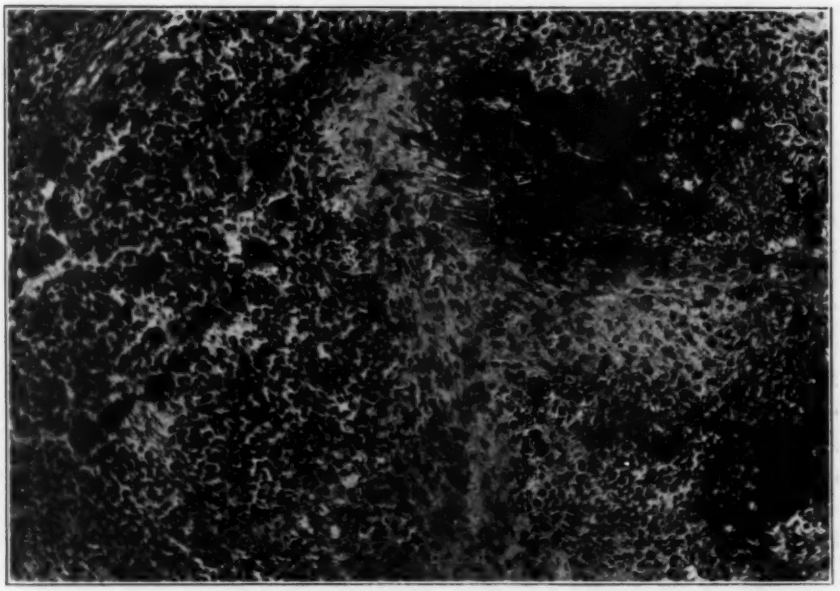

Fig. 11.—Benign central giant cell tumor with island of dissolving and partly calcified cartilage.

5. *Telangiectatic Giant Cell Tumors.*—In 1894 a portion of a central giant cell tumor was submitted to Dr. T. M. Prudden at Columbia for diagnosis and prognosis. It came from a growth which occupied a large lower segment of the shaft of the tibia in a girl, aged 14 years. The tumor was described as extremely vascular. After much discussion, on account of the presence of numerous typical giant cells, the tumor was pronounced benign. Curettage was recommended and performed. Several years later we were informed that the patient recovered, and that her leg was sound.

The structure showed very wide blood spaces separated by thin strands of spindle cell tissue lined by many giant cells. The spindle cells resembled those of the ordinary giant cell tumor.

That the course of central telangiectatic tumors with giant cells is not always favorable is shown by a case illustrated by Figures 12 and 13. The subject was a child of 10 years, in whom the head of the humerus was completely excavated by a bloody mass in which no tumor tissue could be detected on gross examination. Section revealed thin strands of tumor tissue composed of spindle cells with hyperchromatic nuclei. These inclosed wide blood spaces lined by numerous giant cells with multiple small nuclei which again were relatively hyperchromatic. Interscapular-thoracic disarticulation was performed; but the patient

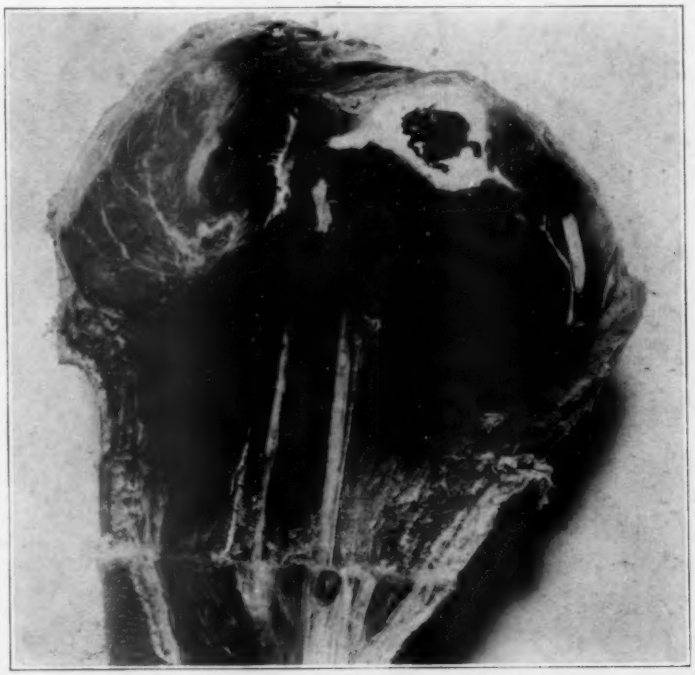

Fig. 12.—Telangiectatic osteogenic sarcoma of head of humerus; malignant bone aneurysm, in a child of 10 years; pulmonary metastases.

is said to have died of pulmonary metastases four months later. This was not confirmed by necropsy. This case may well be classed as a malignant bone aneurysm. On account of this observation it seems proper to urge that more attention should be paid to the main tumor tissue than to the giant cells in the diagnosis of doubtful cases of this type.

6. *Borderline Cases of Giant Cell Tumors.*—Some bone tumors, mainly central in location, are found to have involved much of the neighboring bone shaft which is eroded or perforated, while the tumor tissue early penetrates the soft tissue and fails to throw out a uniform

limiting shell of bone. This anatomic condition is not easily distinguished in the roentgenogram from some osteogenic sarcomas; but careful palpation, roentgenograms taken from several angles, and surgical exploration reveal an absence of the extensive involvement of periosteum which is nearly constant in osteogenic sarcoma. The periosteum in these cases is generally quite intact beyond the main tumor mass.

The structure consists of numerous rather large spindle cells with vesicular nuclei which exhibit some, but not pronounced, hyperchromatism. Intercellular strands are scanty or absent. By hydropic imbibition the cells may appear polyhedral. Giant cells are scanty or absent in many areas but appear in groups, often in the clefts or

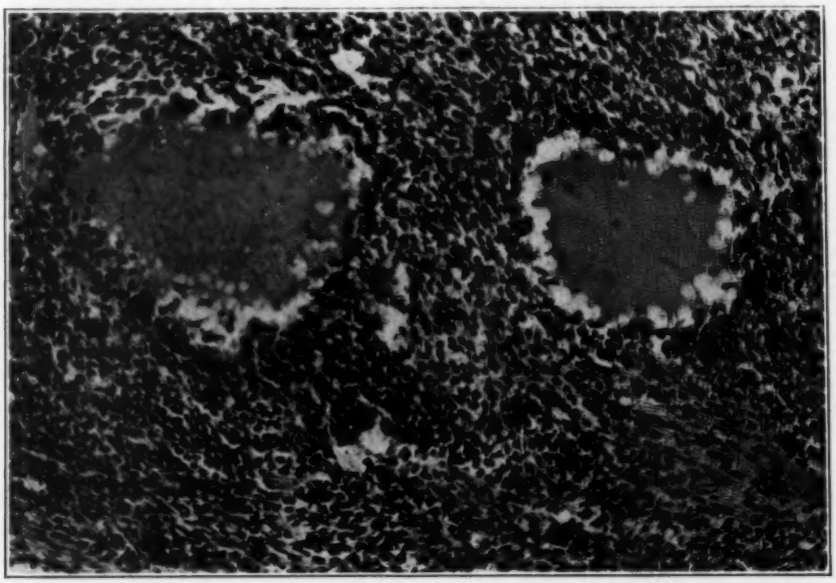

Fig. 13.—Structure of a telangiectatic osteogenic sarcoma; tissue from the outer shell of a highly vascular tumor; round and spindle cells with hyperchromatic nuclei enclosing blood sinuses; same case as Figure 12.

sinuses of tumor tissue. They are not so large as the giant cells of the ordinary giant cell tumor, and the nuclei, while multiple, are larger and more hyperchromatic. The diagnostic difficulties are increased when only curetted fragments of the tumor are available. Such tumors offer a difficult problem for the pathologist and for the surgeon. My colleagues and I have adopted the policy of designating these tumors as borderline tumors of the giant cell type and of giving a guarded prognosis. They are prone to recur after curettage; but I have not known them to produce metastases even after repeated insults.

While they probably belong with the benign giant cell tumor and are connected with the absorption of bone or cartilage, it seems possible that osteoblasts may participate in the proliferation and endow the process with more aggressive qualities than belong to the strictly benign tumors (Fig. 14).

7. Secondary Giant Cell Structure in Malignant Osteogenic Sarcoma.—Since the peculiar giant cells of the benign tumor occur whenever bone is being absorbed and since these structures signify in general a type of foreign body giant cell, one should be prepared to find them in malignant osteogenic tumors surrounding blood extravasations, or following infection, or surgical trauma. Under such

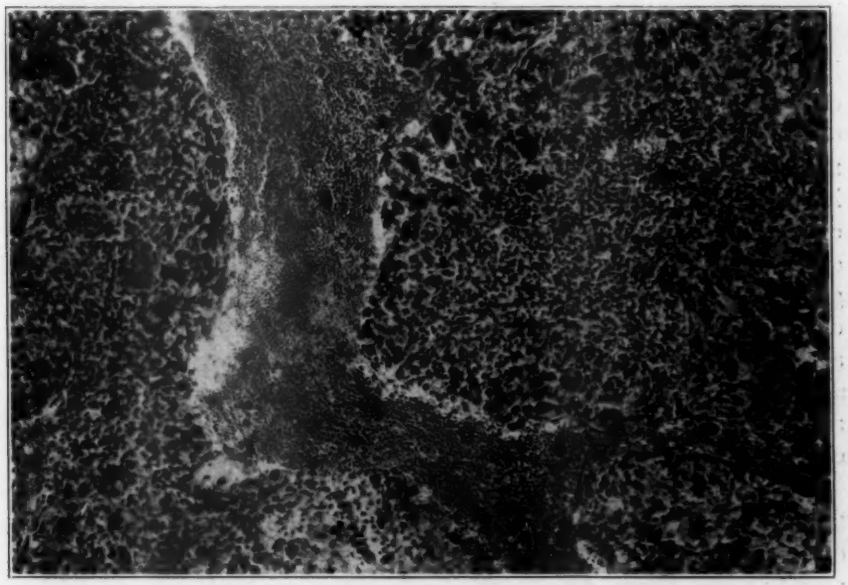

Fig. 14.—Benign giant cell tumor, low magnification; giant cell with many compact nuclei; polyhedral and spindle cells; many small lymphocytes.

conditions they not infrequently appear in malignant tumors and may lead to an erroneous diagnosis by the pathologist when only small portions of tissue are available. These and other considerations have led me to take the position that cutting into bone tumors and removing a small piece for diagnosis is generally hazardous. The diagnosis of bone tumors can safely be attempted only when all of the clinical history and roentgenograms are available. With such data carefully analyzed, the probatory incision is usually found to be unnecessary; and it is not too much to say that the gross anatomy of the lesion is often a safer guide to a correct clinical conception of the disease than the variable and uncertain structure of a small piece of tissue. Doubt-

less there are cases in which both classes of evidence are needed; but they constitute a minority of the group and the microscopic evidence is often indecisive.

The foregoing review of the conditions under which giant cells of the epulis type may be found in bone tumors reveals the difficulties which surround microscopic diagnosis in this field. When the giant cells form the major portion of the tumor, the process is almost invariably lacking in aggressive growth and clinical malignancy; but when they become scanty and are associated with many spindle cells and compact polyhedral cells, the tumors as a rule are more aggressive, while in some cases in which the giant cells are associated with other, more numerous, tumor cells of malignant histologic character the tumors, as in the malignant bone aneurysm cited, are quite malignant. In addition, there is the occasional occurrence of epulis giant cells in inflamed and degenerating osteogenic sarcoma. Under these circumstances, it seems desirable to restrict the importance of the presence of giant cells in the diagnosis of bone tumors, and to emphasize more strongly the importance of the main tumor cells. Furthermore, it seems probable that further study of the origin of these benign central tumors will lead to the definite subdivision of the group based on exact histogenesis and general etiology. The demonstration of a group of these tumors as probably derived from the absorption of cartilage is perhaps a step in this direction. The xanthomatous tumors also are peculiar in many respects and suggest that they too enjoy some peculiar conditions of origin. Osteitis fibrosa seems to be associated only with the benign vascular cystic tumors composed chiefly of giant cells of large size.

A more satisfactory term should be found to designate this group of tumors, and one which lays less emphasis on the giant cells. Central osteogenic sarcoma or benign central sarcoma may be suggested as worthy of consideration.

OSTEOGENIC SARCOMA

Of this, the main malignant tumor of bone, four distinct groups should be recognized, because of their peculiar gross anatomy, microscopic structure and clinical course. These are: (1) periosteal sarcoma; (2) subperiosteal and medullary sarcoma; (3) telangiectatic sarcoma, and (4) sclerosing osteogenic sarcoma.

I have previously urged the recognition of only three groups of osteogenic sarcoma, merging the first two groups of the present list for the sake of simplicity; but the facts demand the sacrifice of simplicity in the interest of more accurate knowledge. A large number of bone tumors are *extra*periosteal, while many others are *sub*periosteal and invade or originate in the marrow cavity. On dissection these tumors are found to be quite different in gross anatomy; in structure,

Fig. 15.—Malignant ossifying extraperiosteal sarcoma, which produced pulmonary metastases.

they are quite divergent, and the clinical courses are far from parallel. These contrasts suggest essential differences in the conditions of origin of the tumors.

1. *Periosteal Sarcoma.*—The extracortical position of these tumors is quite characteristic. In fact, the true periosteal sarcoma appears to originate from the periosteum itself or from the outer layers, leaving

Fig. 16.—Extraperiosteal osteogenic sarcoma; same case as that shown in Figure 15.

the bone shaft intact or slightly eroded, whereas other osteogenic sarcomas are subperiosteal and grow beneath the periosteum, separating it from the shaft over a wide area by a fusiform mass of cellular tumor tissue. These relations are indicated in the accompanying sketch (Fig. 20), and they become quite apparent in Figures 15, 16, 17 and 19.

Fig. 17.—Malignant spindle cell extraperiosteal and capsular sarcoma, fungating through the skin at line of diagnostic incision; infection with rapid enlargement from inflammatory edema.

The roentgenogram shows an intact or slightly eroded shaft running through a solid tumor mass which lies at one side and which is attached to a segment, often narrow, of the periosteum. Some of these tumors arise mainly from the capsule of the joint, but a pure capsular sarcoma is rare.

The small area of periosteum involved and the firm encapsulation frequently observed suggest that in such cases an effort may be made at local excision. Some periosteal sarcomas are dense fibrosarcomas which recur locally but which have only a moderate tendency to produce metastases. They also suggest conservative treatment.

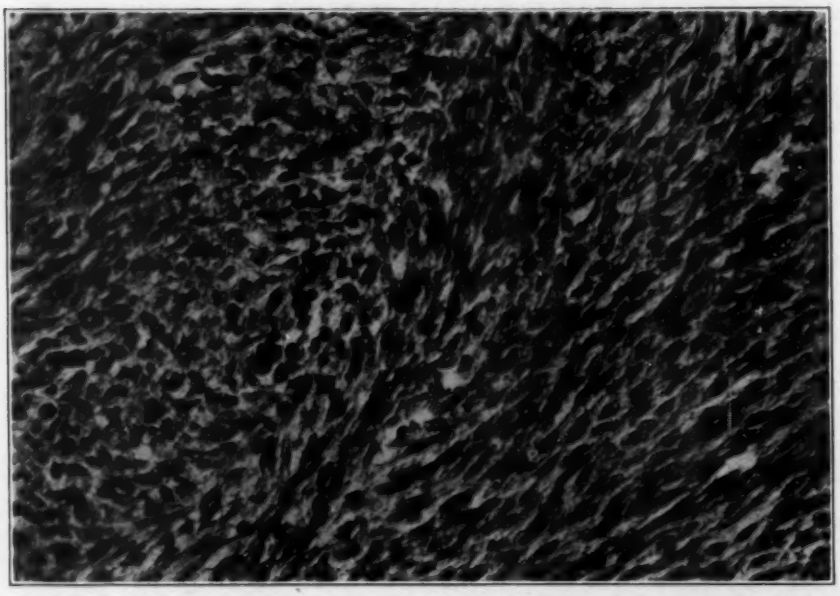

Fig. 18.—Structure of extraperiosteal and capsular osteogenic sarcoma; same case as Figure 17.

Most periosteal sarcomas produce bulky rounded solid growths which long remain encapsulated, pushing the soft parts before them. When forming cartilage, they may reach enormous dimensions.

The texture of periosteal sarcomas varies. Some are cellular, soft, crumbly, rapidly growing and extremely malignant. A tumor of the humerus gave myriads of metastases in nearly every portion of the body from calvarium to heel, while the pancreas was completely replaced by tumor tissue, composed of small spindle cells. A cellular tumor of the patella proved fatal six weeks after the originating injury was received.

Most of the tumors are firm because of the presence of much intercellular stroma, which appears in the form of stalactite strands of

hyaline, osteoid or osseous tissue, or masses of cartilage. The metastases may produce bone.

The structure of the periosteal sarcoma is usually specific and easily recognized. It presents spindle cells, small or of moderate size,

Fig. 19.—Solid central and subperiosteal osteogenic sarcoma; the sharp limitation at epiphyseal line may be noted.

but usually presenting hyperchromatic nuclei. Cell bodies are not always easily demonstrable, so that some of these tumors may pass as round cell sarcoma. In other cases the spindle cells are quite large,

and with increasing stroma they tend to become large and sometimes polyhedral.

Differing markedly from these malignant cellular growths is a series of cellular fibrosarcomas in which hyaline and fibrous stroma exceeds the bulk of the cells. Such tumors are not, as a rule, malignant. They recur locally after excision, but are slow to produce metastases. They probably form the majority of cures of osteogenic sarcoma by amputation (Figs. 21 and 22).

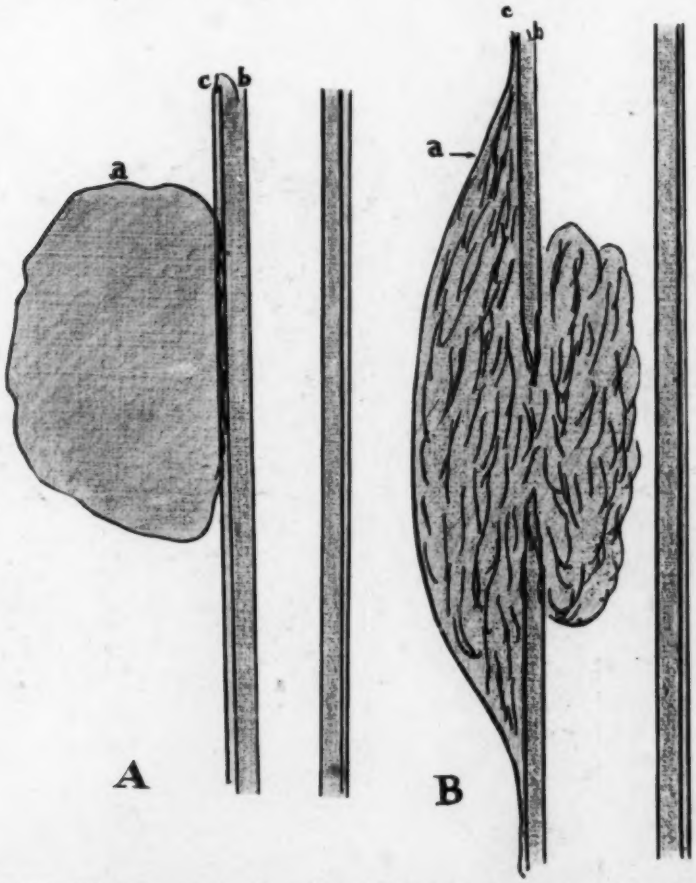

Fig. 20.—Diagram contrasting the relations of the extraperiosteal sarcoma and medullary and subperiosteal sarcoma: *A*, periosteal sarcoma; *B*, medullary and subperiosteal sarcoma; *a*, tumor; *b*, shaft and *c*, periosteum.

The diagnosis between hyperplastic callus and productive periostitis is not always easy, and must be based on general familiarity with both processes. Mistaking exuberant callus and productive periostitis for sarcoma is a very common error which may be avoided if the microscopist will insist on having unmistakable neoplastic characters

before concluding that a malignant process exists. Malignant bone-producing tumors very rarely develop within three weeks after a trauma. Periostitis usually covers a wide area, while tumors are localized.

2. *Solid Subperiosteal and Medullary Sarcoma.*—The most frequent form of osteogenic sarcoma involves marrow, shaft and subperiosteal tissue. The cancellous tissue toward the end of the diaphysis is converted into a solid tumor mass which extends up the marrow cavity, and after considerable delay may cross the epiphyseal line into the epiphysis. At the same time the shaft is destroyed and the tumor spreads beneath the periosteum, producing a fusiform swelling which gradually encases the bone. In the earliest cases which I have

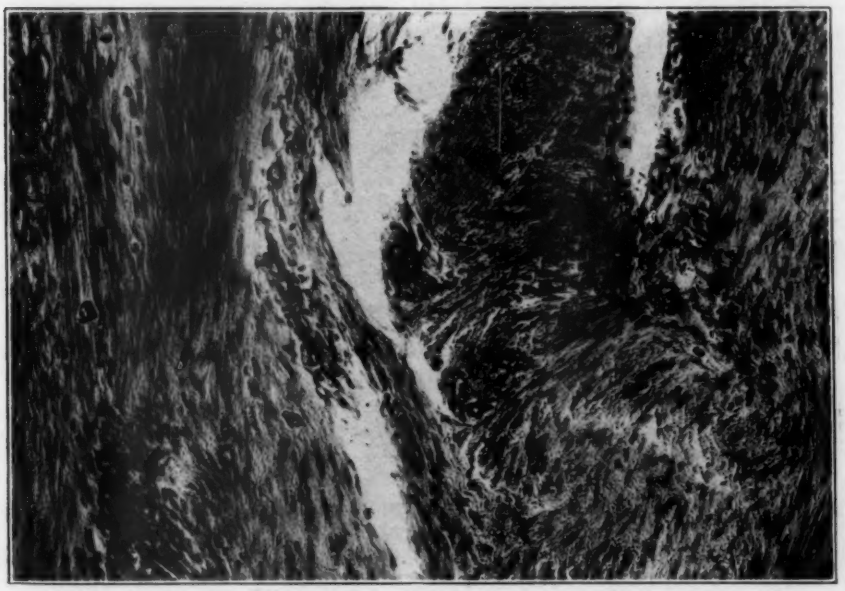

Fig. 21.—Large spindle cell, highly fibrous periosteal sarcoma.

dissected the lesion was about equally developed in both locations, medullary and subperiosteal. The separated periosteum long remains as a resisting capsule; but eventually it is perforated, after which the tumor process rapidly invades the soft parts (Fig. 19).

Occasionally, these tumors spread widely over large segments of bone. I have seen most of the ilium, pubes, ischium, and upper half of the femur covered and infiltrated by cellular subperiosteal and medullary sarcoma.

The tumor tissue is solid, opaque and cellular. Usually there is considerable stroma, of osteoid character, which renders the growth firm and resistant. Bone formation is not prominent; but irregular

islands may appear throughout the medullary portions, and radiating striae beneath the periosteum. Hemorrhage and necrosis belong to the rapidly advancing cases. Combinations with the sclerosing type of osteogenic sarcoma are not infrequent.

The structure exhibits considerable variations. Most of the tumors consist of spindle, rounded, and polyhedral cells, while mononuclear giant cells are common. In some cases, probably concerned with cartilage, the cells are large and polyhedral. The stroma is usually abundant, and of hyaline, cartilaginous, osteoid, or osseous type. Bone production and absorption go hand in hand in the same territory. The blood vessels consist of capillaries and clefts between tumor cells,

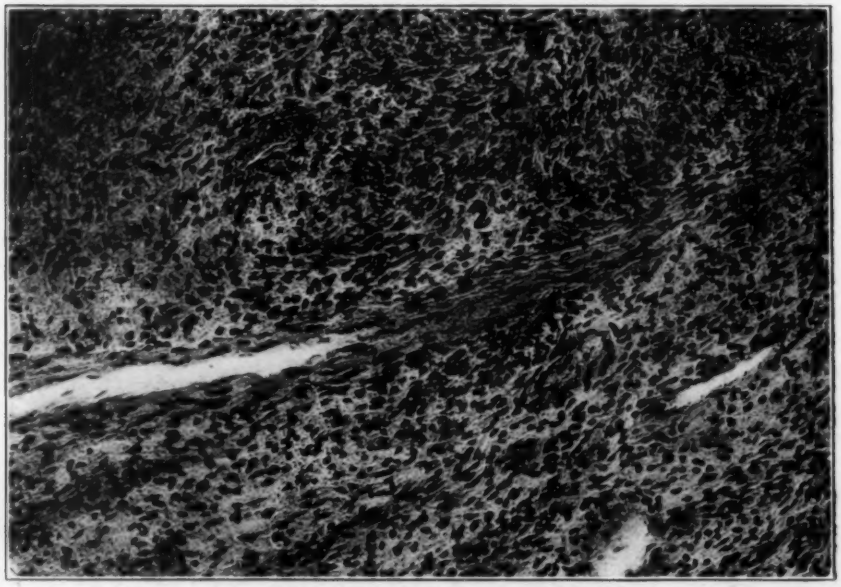

Fig. 22.—Spindle cell fibrosarcoma of periosteum.

and of larger vessels lined by tumor tissue and through which cell emboli readily pass (Figs. 24 and 25).

In the roentgenogram the most striking feature is the elevation of the periosteum by a fusiform subperiosteal tumor. A bony capsule such as is seen about benign central tumors is missing; but irregular extracortical deposits of bone may be seen. The medullary region is usually opaque and in sclerosing types it may be quite dense. The cortex is generally obscured or destroyed (Fig. 23).

3. *Telangiectatic Bone Sarcoma.*—This is a characteristic gross anatomic picture (Fig. 26). Its exact point of origin is not narrowly defined, but it early destroys the shaft and grows expansively in all directions, obliterating the marrow cavity and perforating the distended

periosteum and its shell of bone. Vascular tumors may pulsate. In several rapidly progressing cases, I have found the lower 2 inches (5 cm.) of the femur sequestrated beneath the periosteum and lying in blood clot. Combinations with cellular solid central and periosteal tumor masses are common.

Fig. 23.—Osteogenic sarcoma.

At the other extreme are cases in which there is comparatively little tumor tissue, but widely dilated blood spaces separated by strands and walled off externally by narrow layers of malignant tumor tissue.

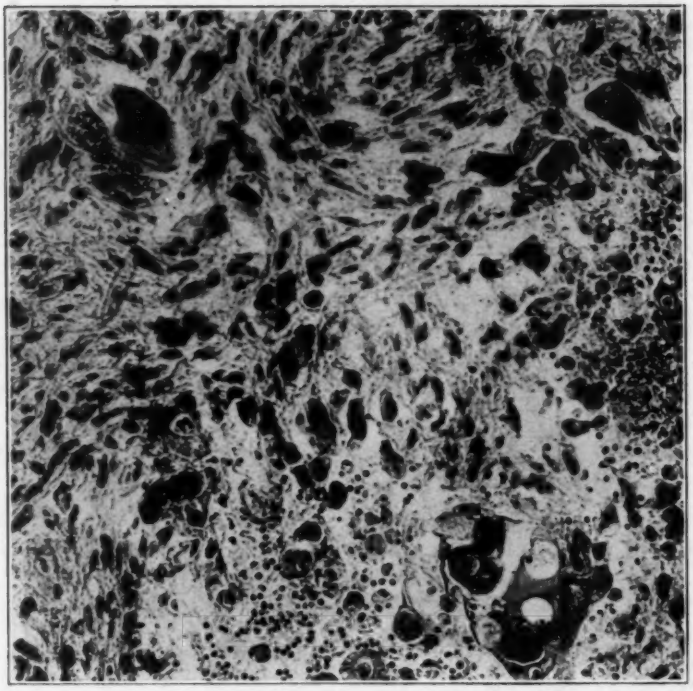

Fig. 24.—Malignant osteogenic sarcoma with giant cells.

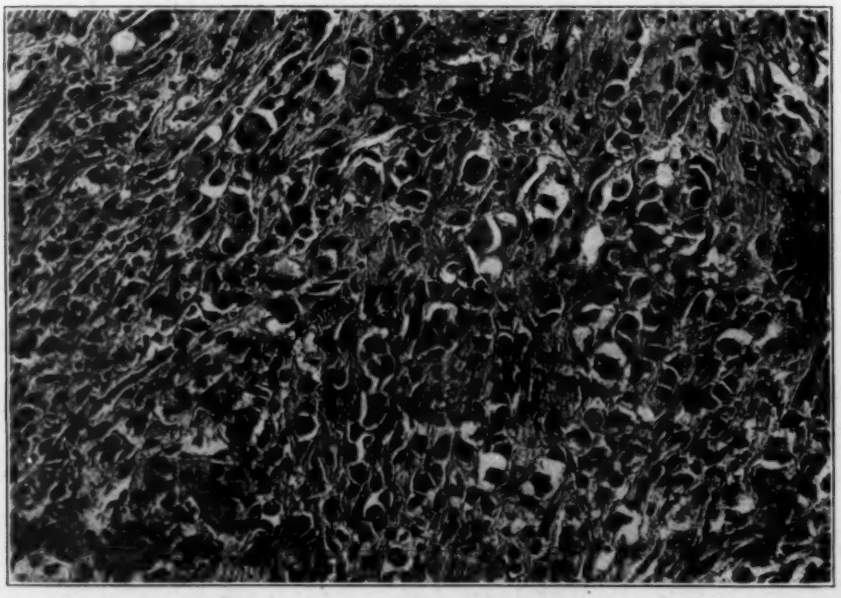

Fig. 25.—Structure of osteogenic sarcoma; large polyhedral and spindle cells in fibrillar and osteoid stroma.

These are the true malignant bone aneurysms (Figs. 12 and 13). This type of tumor is practically limited to young subjects. Few patients survive more than a year, and no cures by any method appear to have been recorded.

Fig. 26.—Telangiectatic osteogenic sarcoma.

All of these variations and combinations indicate that the disease is essentially one and the same process, which originates from osteoblasts and destroys periosteum, bone shaft and marrow.

4. *Sclerosing Osteogenic Sarcoma.*—This term was employed by Virchow to designate certain bone-producing sarcomas, mainly central

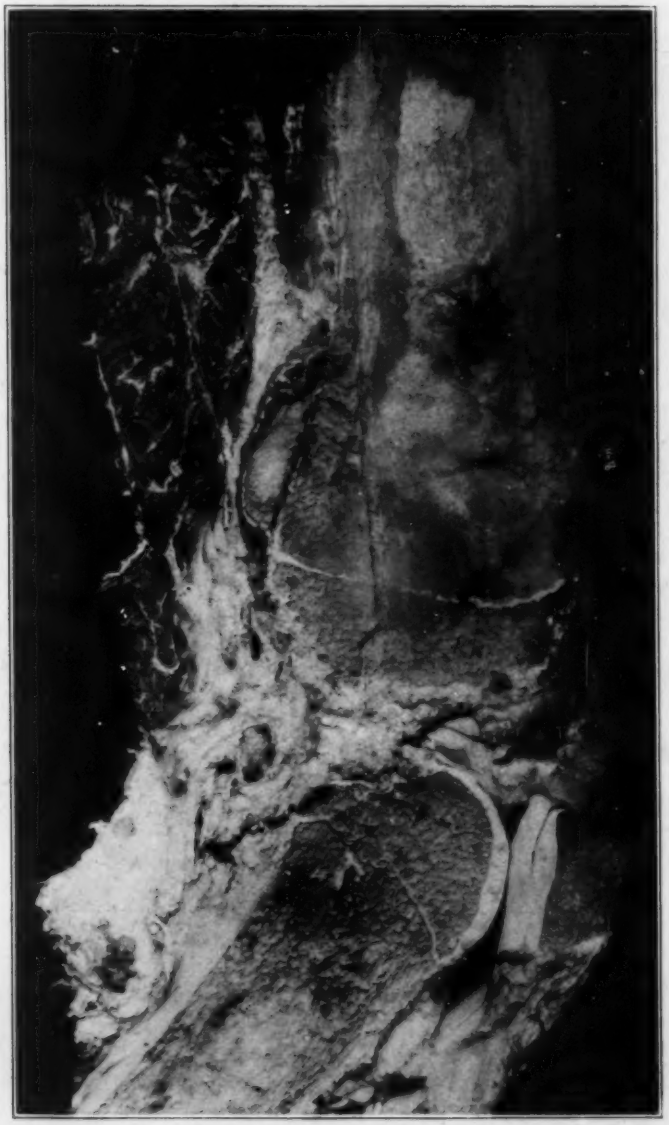

Fig. 27.—Sclerosing osteogenic sarcoma of femur; fusion of thickened cortex with central mass of ossifying tumor; extension up marrow cavity and into periosteum.

in location, but involving periosteum, shaft and marrow cavity, and transforming the end of the bone into a bulky solid mass of hard, occasionally ivory-like, bone.

Minor variations in this process are not uncommon. The periosteum usually remains unbroken; but it may be perforated early, releasing a portion of the tumor which grows in more cellular form, invading the soft tissues. The roentgen ray shows the club shaped central mass of dense bone with widening and obliteration of shaft. The picture is unlike that of any other process in bone (Fig. 27).

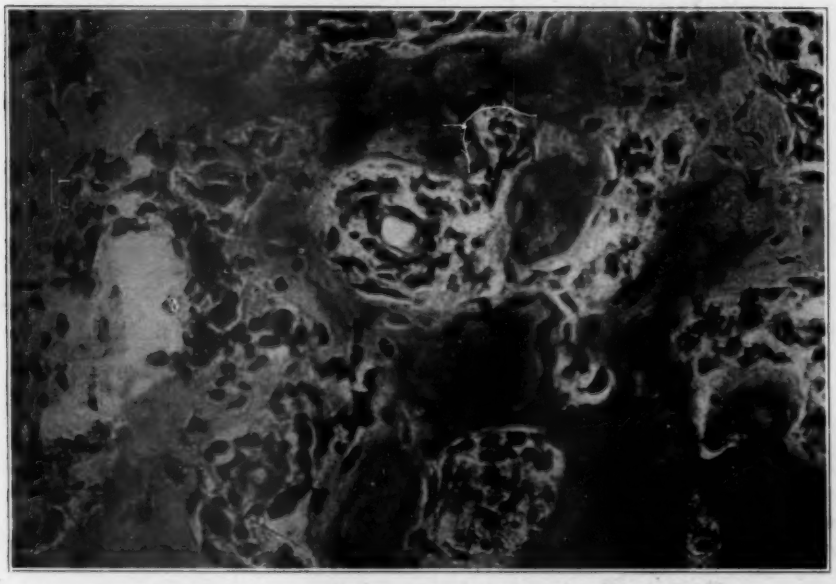

Fig. 28.—Structure of sclerosing osteogenic sarcoma; large spindle and polyhedral cells lying in osteoid and osseous tissue; nuclei large and hyperchromatic.

The dominating histologic feature is the production of much intercellular material in the form of hyaline osteoid tissue or dense bone. This material is at first cellular but eventually becomes very compact, hard, and acellular (Fig. 28). In the advancing peripheral portions are blood vessels lined by tumor cells, through which metastases readily occur.

The progress of the disease is slow, from one to two years elapsing before marked swelling of the bone appears, and from five to twenty-five years passing before the usual fatal termination is reached. Yet the prognosis is poor, since metastases seem to occur early, although some years may elapse before pulmonary signs are detected.

ETIOLOGY OF OSTEOGENIC SARCOMA

It is difficult to find any adequate hypothesis regarding the causation of osteogenic sarcoma. Trauma rather frequently precedes the outbreak of the disease but has been noted only in a minority of cases, and is of itself an inadequate explanation. It is possible to conceive that traumatic hemorrhage and separation of minute fragments of bone may tend to release the vigorous regenerative capacity of osteoblasts; but the atypical and lawless form of the regeneration always evades our grasp. Definite fractures are seldom followed by sarcoma although exuberant callus closely approaches in structure osteogenic sarcoma. Some element of tissue predisposition must be involved and it seems probable that this factor may consist in an abnormal blood supply in the affected part, providing excessive nutrition. If such a factor actually exists it works more often alone than with trauma. Typical osteogenic sarcoma almost invariably begins *in the end of the diaphysis* and long fails to cross the epiphyseal line. This relation suggests that a vascular and nutritional disturbance may reside in the branches of the main nutrient artery but not in the capsular vessels which supply the epiphysis. Multiple osteogenic sarcoma, affecting the ends of several long bones, of which I have seen one case so interpreted, favors the idea that the disease is dependent on some congenital disturbance in the structure of the bones.

UNIDENTIFIED TYPES OF BONE SARCOMA

In the group of osteogenic sarcoma one must include certain malignant cellular tumors, the origin and nature of which are still quite undetermined. One not infrequently encounters cellular medullary and subperiosteal tumors in which the hyperchromatic cells grow diffusely without producing bone or any stroma.

The nature of these tumors remains an unsolved problem in which several possibilities may be considered: (1) It is possible that osteoblasts may proliferate so rapidly as to produce a tumor tissue composed of rounded or polyhedral or short spindle cells, entirely free from intercellular material. (2) An endothelial origin of some of the cellular tumors is also to be considered; but the necessary proof is difficult to secure, and unless the evidence is quite convincing the diagnosis of endothelioma should not be entertained. (3) It is always a safe resort to assign undifferentiated round and polyhedral cell tumors to the group of myelomas; but this plan does not assist in unraveling that miscellaneous class of neoplasms. (4) The perithelial cells of blood vessels are a source of somewhat specific tumors in many situations; but there is no definite evidence that angioblastic cells produce the cellular tumors of bone. (5) The increasing recognition of neuroblastoma, especially in young subjects, raises the suspicion that some

of the cellular tumors of bone may be derived from the neuroblast; but the characteristic rosets on which alone the diagnosis of neuroblastoma may safely rest, have not been demonstrated in bone sarcoma. (6) One may draw into the possible sources of tumors aberrant organ and tissue rests, the existence of which in bone or bone marrow is mainly hypothetic. (7) A metastatic origin of atypical cellular bone tumors is always to be kept in mind; but this explanation will not apply to most of the tumors in question.

These speculations seem permissible mainly to emphasize the fact that the territory of cellular bone tumors still requires much further exploration. Yet there is a practical value in knowing that such unidentified tumors exist, so that peculiarities in age incidence, location, structure, and clinical course, and paradoxic cures by surgery, roentgen ray, and radium, may not be attributed to the well known malignant bone tumors.

MYELOMA

Only a brief outline of the main features of this extensive, but comparatively rare, group of tumors can be undertaken at this time.

Myelomas are tumors derived from the specific bone marrow cells. Granular myelocytes, lymphocytes, and nucleated red blood cells are the three specific cells of bone marrow, and tumors of each of these cells are observed. The commonest form of myeloma is, however, composed of plasma cells, the origin of which is still somewhat uncertain. The weight of opinion favors an origin from lymphocytes or from endothelial cells. There are thus four histologic varieties of myeloma: (1) plasma cell tumors; (2) lymphocytoma; (3) myelocytoma, and (4) erythroblastoma.

These tumors have certain common features which separate them sharply from osteogenic sarcoma. While often single they are usually multiple. Eventually, they may become widely diffused or systemic. They readily destroy bone by diffuse absorption or sharp perforation, but never produce bone. Visceral metastases develop slowly or not at all, so that many cases come to necropsy without metastases. The regional lymph nodes are not infrequently involved. The presence of involved regional nodes is almost certain evidence against osteogenic sarcoma, although in a few cases of this disease the nodes appear to have sifted out cells which ordinarily travel through large blood channels.

The location of myelomas is peculiar. They choose by preference the midportions instead of the ends of the bones, often involving considerable segments or later the whole of the marrow cavity. They also affect the vertebrae, ribs and skull, which are seldom the sites of osteogenic sarcoma. Passing through the bone, myelomas infiltrate the soft tissues, without, as a rule, producing the bulky tumors and destruc-

tive effects of other sarcomas. Rapidly destroying bone, they early lead to spontaneous fractures, or collapse of joints, or crushing of vertebral bodies with paraplegia (Fig. 29).

A peculiar cachexia and anemia usually accompany myeloma, due to the destruction of blood-forming marrow. Bence-Jones proteinuria is occasionally present. The prognosis of all forms of myeloma is unfavorable, owing to the multiple and systemic nature of the lesions. Yet solitary myeloma is probably curable by excision or amputation. Of the recurrences and extensions it is difficult to determine whether they are metastases or multiple primary new growths.

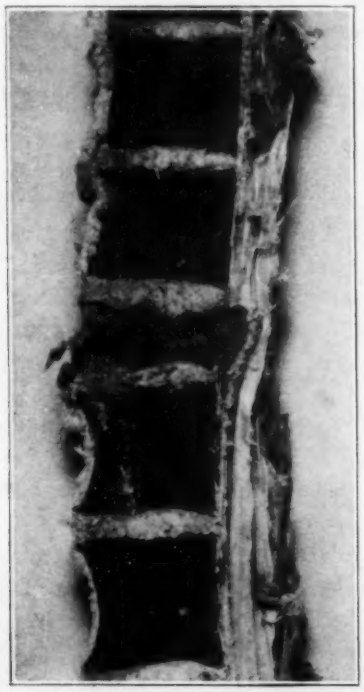

Fig. 29.—Plasma cell myeloma of vertebral body, causing collapse of vertebra and paraplegia.

Like other lymphoid tissues, myeloma recedes rapidly under roentgen-ray and radium treatment and the bone is partially restored; but the ultimate prognosis remains unfavorable because of extensions and metastases.

The diagnosis of myeloma can usually be made on the general clinical features and on the roentgenograms. The medullary location, the preference for the midportions rather than the ends, the sharp perforation or diffuse absorption of bone are rather specific roentgenologic features; yet diffuse endothelioma produces much the same effects

as solitary myeloma. Tissue excised for diagnosis shows a diffuse growth of round cells of the various types occurring in marrow. Myeloma is the only true round cell tumor occurring in bone. Hence the term "round cell sarcoma" should be eliminated from the discussion of bone tumors and the more exact histogenetic designations employed. The various cell types in myelomas can usually be recognized in sections, since plasma cells, lymphocytes, granular myelocytes, and hemoglobin-holding cells are peculiar. Yet owing to neoplastic variations in cell structure and degenerative processes, there has been extensive debate regarding the exact nature of many cases, and the exact identification of every case is impossible.

The several varieties of myeloma differ somewhat in their general behavior.

1. *Plasma Cell Myeloma.*—This is usually multiple and often occurs in the form described as Kahler's disease, with extremely numerous painful perforating tumors affecting many bones throughout the body, without notable visceral metastases, with early cachexia and with proteinuria. Yet I have observed solitary plasma cell myeloma of the sternum, tibia, and femur, and Greenough, Simmons, and Harmer report solitary myeloma of the ilium and humerus.

Large mononuclear nongranular cells occur in rapidly progressive cases which involve several bones and produce extensive metastases. In a young patient, observed by Norris, very large round cells with hyperchromatic nuclei occurred in widely distributed bone tumors and in very bulky metastases in all the organs. In these cases it is impossible to determine the cell of origin.

2. *Diffuse Lymphocytoma.*—This occurred in a case that I followed for several years. The disease first appeared in the humerus, the entire shaft and the epiphysis being widened and the bone distorted and largely absorbed. The progress was relatively slow. Under roentgen-ray treatment the greatly swollen arm was reduced to normal dimensions and the shaft was largely restored. The patient, a young man, resumed his work for a period of two years, and passed out of control; but it was learned that the disease reappeared in other locations, with a fatal result, about five years after the inception. The structure of the humerus tumor showed a diffuse growth of typical small lymphocytes.[5]

3. *Large Mononuclear Cells.*—These cells with prominent granules of variable staining characters I have observed in three cases.

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5. Ewing, James: Neoplastic Diseases, Ed. 2, Philadelphia, W. B. Saunders Company, 1922, pp. 294-295.

One of them involved the whole marrow cavity of the humerus of an adult male, destroyed the shaft over the upper half and produced a bulky infiltrating extensively necrotic tumor of the muscles and fasciae. Shoulder-joint amputation was soon followed by recurrence and generalization of the disease. Considerable infiltration by lymphocytes and extensive necrosis suggested a syphilitic process; but the wide areas of large hyperchromatic granular cells and the later course demonstrated the myelomatous nature of the disease.

This form of myeloma appears to have escaped definite attention in the literature of bone sarcoma, although several authors have described scanty neutrophil granules in the cells of myeloma.

Fig. 30.—Myeloma of femur involving a large portion of the shaft; loosely packed large round cells.

4. *Hemoglobin-Holding Cells.*—These have been found in myeloma by Ribbert [6] and by Norris. In Ribbert's case the largest tumors were in the ribs and smaller growths were found in the vertebrae and skull. The tumors presented a striking brownish-red appearance; and hemoglobin in abundance was found in the tumor cells. In a similar case observed by Norris [7] in Bellevue Hospital the cells were rich in hemoglobin.

6. Ribbert: Centralbl. f. Path. **15**:337, 1904.
7. Norris: Proc. New York Path. Soc. N. S. **6**:128, 1906.

Fig. 31.—Myeloma of tibia, composed of small round cells with hyperchromatic nuclei.

The Prognosis and Treatment of Sarcomas of Bone

The increasing knowledge of the natural history of bone tumors furnishes a basis for reconsidering the treatment of these diseases. I believe that the present state of our knowledge and the additional resources of roentgen ray and radium demand that the whole subject of the prognosis and treatment of bone sarcoma should be reopened and readjusted to meet the present situation and bring the control of these diseases more nearly in line with present possibilities. It does not require an extensive experience with surgical literature, to say nothing of actual surgical practice, to force the conclusion that the results now generally obtained with this group of diseases are far below a reasonable standard.

Generally speaking, the diagnosis of malignant bone tumors is accomplished in the late stages of the disease, after long delay has been incurred by considering every other possibility, and not a few impossibilities. Experience with many of these cases at the Memorial Hospital shows that in the presence of definite signs of bone sarcoma, persistent pain and loss of function, these patients are generally treated for inflammatory conditions and the last possibility to be considered is sarcoma. Often until the terminal stages, treatment has been directed toward the alleviation of rheumatism, neuralgia, syphilis, osteomyelitis, sprain, endocrine disturbance, etc. All the modern laboratory methods for the quantitative study of the secondary phenomena of disease have been freely employed; but the diagnosis of a lethal disease has not been made in time to be of service. Even in the face of indubitable signs and pathognomonic symptoms of well established bone sarcoma I have known experienced surgeons to refuse to accept the diagnosis of malignant tumor.

The main reason for this costly conservatism must be found in the fact that the diagnosis of bone sarcoma is generally accepted as a signal for an immediate surgical operation, either amputation, or excision, or diagnostic incision. As long as this view and this aggressive standard practice prevail so long will the surgeon delay in accepting a grave prognosis for his patient. On the other hand, if the diagnosis were approached more radically, treatment might be much less radical.

I believe that with present resources, the suspicion of bone sarcoma should not be taken as a signal for operation. The diagnosis in the great majority of cases of bone sarcoma can be accomplished on clinical history, roentgen-ray findings, and the results of therapeutic tests with roentgen ray or radium. The therapeutic test is at the same time the best treatment for a large proportion of bone sarcomas. In short, the nonoperative treatment of these diseases is a goal to be aimed at. The main exceptions to this proposal, of which there are many, are found among the early osteogenic sarcomas with which prompt ampu-

tation has effected some cures. There are also complicated cases of other types which demand operation.

Considering first the omission of diagnostic incisions, one finds that the vast majority of cases of bone sarcoma of every type give highly

Fig. 32.—Myeloma of tibia; bony portions of the tumor are dissolving bone apparently displaced from the shaft.

characteristic roentgenograms, which, interpreted in the light of exact and simple clinical data, permit a reasonably accurate diagnosis. The roentgenologic details will not here be repeated; but emphasis may

be placed on the facts that: osteogenic sarcoma almost never affects the middle half of the shaft, but is a disease of diaphyseal ends; erosion or destruction of a segment of shaft is nearly constant in osteogenic sarcoma; the benign central tumors regularly widen the shaft and displace the periosteum with its thin shell of bone, long before more aggressive forms of this disease invade the soft tissue; and myelomas and diffuse endotheliomas involve wide segments of the bone, often the midportions, and cause smooth gradual fading of the shaft. Syphilis, tuberculosis, chronic osteomyelitis and periostitis, and Paget's disease, each presents its own peculiar morphology and

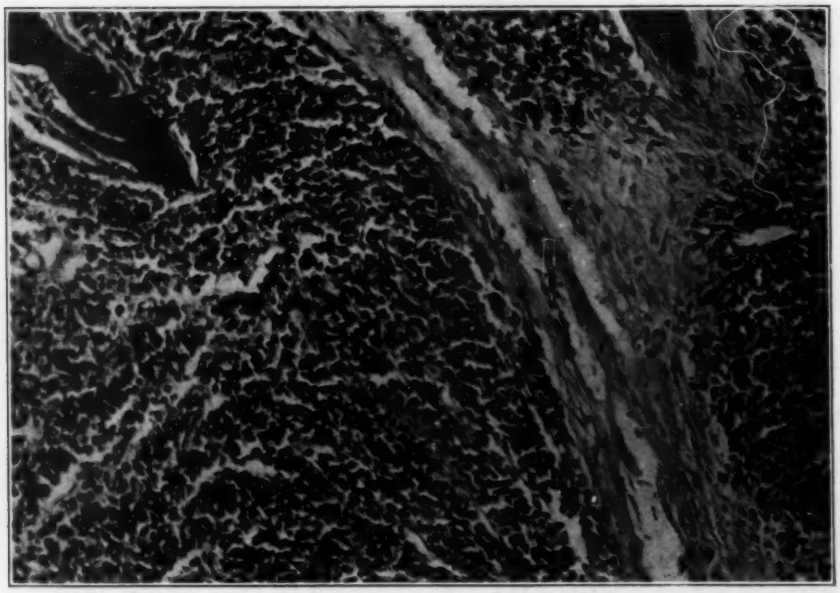

Fig. 33.—Structure of a diffuse myeloma; cells small, round, and polyhedral; type undetermined; same case as Figure 31.

clinical setting, and, with rare exceptions, lacks the specific features of bone tumors. It must be admitted that these interpretations require experience; but no inexperienced person should undertake to deal with bone tumors. When the experienced observer is unable to reach a conclusion, then resort must be made to the diagnostic incision, before amputation is advised.

The therapeutic test is decisive evidence as between certain classes of bone tumors. Myelomas and diffuse endotheliomas melt down rapidly under roentgen ray and radium. These physical agents control the growth of the benign central tumors and cause the gradual restoration of the shaft, while the relief of pain and disability is usually

prompt. With osteogenic sarcoma, roentgen ray and radium have little or no immediate effect on the size or form of the tumor. Chondrosarcomas seem to be wholly unaffected by external radiation.

When the clinical data, roentgen-ray findings, and therapeutic tests have been carefully weighed by an experienced observer, I believe there will be very few cases remaining for diagnostic incision.

When tissue has been removed for diagnosis, the microscope in competent hands will provide an accurate idea of the clinical nature of the disease in the great majority of cases, but not always. Failure to secure a characteristic portion of the tumor, encountering tissues greatly altered by inflammatory or degenerative processes, and inexperience of the pathologist with the very wide scope and confusing variety of histologic features occurring in diseased bone are some of the common sources of error which the surgeon must face who trusts his diagnosis to the microscope. It would be a mistake to overemphasize these hazards; but the more experienced the pathologist, the more he learns to rely on clinical data for clinical diagnoses and the more he urges the surgeon to make his diagnosis on clinical observation, and not to expect too much from the study of small pieces of tissue. As a rule, the microscope reveals the general class of a bone sarcoma; but it often fails to reveal those special features which are so important in forming a clinical estimate of the disease.

The diagnosis having been reached, the plan of treatment may then be determined with adequate reference to the natural course of the disease. In this decision, I would emphasize the necessity of distinguishing not only between the different groups of bone sarcoma but between different cases in the same group. Blanket rules are inadmissible in dealing with cases which differ so widely in their natural tendencies as do bone sarcomas. The slowly growing, encapsulated fibrosarcoma attached to the periosteum presents a very different therapeutic problem from the highly malignant telangiectatic sarcoma, and there is much variation among the cases of benign giant cell tumor.

TREATMENT OF THE GIANT CELL TUMOR

The standard treatment of this disease is by curettage, followed, as a rule, by application to the cavity of some escharotic. A plastic bone operation is sometimes required. The results are generally good. Yet there are several limitations to the success of this radical surgical method. Infection not infrequently follows the curettage, and leads to persistent suppuration, osteomyelitis, or septicemia, since it is difficult to eradicate infection of tumor tissue in the marrow cavity of a long bone. Or the tumor recurs and requires repeated curettages, with advancing destruction of bone, or opening into joints, so that eventually amputation is required. I have observed many cases of this benign

tumor in which all of these unfortunate terminations have resulted in the hands of competent operators. Nor is it unreasonable to assume that the trauma of repeated curettages may transform an originally benign process into one clinically malignant. Even the mechanical forcing of viable cells through open blood vessels and the production of metastases seem quite within the range of possible results of surgical trauma, especially in cellular tumors.[8]

All of these hazards may be avoided by treating these patients by roentgen ray or radium. Both of these physical agents control the growth, soon relieve pain and disability, and permit the gradual restoration of the shaft. The experience at the Memorial Hospital with a considerable series of cases during the past few years has demonstrated, in my opinion, that treatment by roentgen ray or radium should be adopted as the method of choice in uncomplicated forms of this disease. Recently, Jungling[9] has reported the cure by roentgen-ray treatment of a large medullary sarcoma of the upper end of the femur, and at the same time he records the spontaneous regression of two other cases located in the humerus and fibula. This plan, however, calls for a period of several months of observation, for while pain and disability are usually relieved promptly, the restoration of the shaft is slow. If this method fails after adequate trial, then it is time enough to consider curettage, or, if there is great destruction of tissue, amputation.

For a successful result, it is highly important that the skin and tumor capsule should not be incised for diagnosis, since the scar may break down under repeated radiation, and infected cases as a rule do badly. The insertion of radium tubes into the cavity after curettage is not a very satisfactory method, since such radiation renders the tissue more susceptible to infection, and adequate dosage may cause chronic osteitis or bone necrosis. The best method is external radiation through the intact skin. The capacity of the physical agents to deal successfully with the various forms of the benign giant cell tumor is clearly dependent on the cellular structure and delicate blood vessels of the tumor tissue.

Myeloma.—Owing to the multiple or systemic distribution of most cases of myeloma the prognosis of the disease remains unfavorable under any form of treatment. Since these cellular lymphoid tumors are very susceptible to roentgen ray and radium, these agents would seem to deserve first choice in treatment. Yet since little is known

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8. Since this article was written, I have obtained all the data in a case demonstrating the transformation of a benign giant cell tumor of the tibia into a malignant large spindle cell sarcoma as a result of repeated curettage, infection and radium treatment, and terminating, after amputation, in death from pulmonary metastases. This case will be fully reported later.

9. Jungling: Strahlentherapie **12**:178, 1921.

regarding the mode of extension of myeloma, one may assume that a prompt amputation may at times forestall metastases. The available reports in the literature, as well as my experience with a few of these rare cases, does not encourage the belief that amputation accomplishes much in this disease. For multiple cases affecting the bones of the skull or trunk, roentgen ray and radium constitute the sole resource, and so far as the local tumor is concerned they are effective.

Endothelioma.—So far I have been able to learn there are no reports of surgical cure of angio-endothelioma, and no record of treatment by physical agents. Owing to early metastases and multiple origin, the prognosis of this disease must remain unfavorable. On account of the vascular and cellular structure of the tumors, it is to be hoped that the effects of the physical agents on this process will be submitted to an early test.

Diffuse endothelioma as already stated, regresses so rapidly under roentgen ray or radium as to call for this plan of treatment in every case. Yet I would again emphasize that sufficient time has not elapsed to determine the final outcome of cases that have responded well to radiation. At the present writing, four of ten patients are dead: three from multiple tumors, one from "acute mania"; two are without signs of disease; one has progressed favorably for a year, and three have not been traced. Until more is known regarding the nature of this disease, it can only be said that the physical agents seem to control the local process, and that amputation should be withheld until its indications are more clearly defined.

Osteogenic Sarcoma.—While the highly lethal character of this disease is perhaps its most impressive feature it is probable that isolated surgical cures have been obtained for nearly every bone of the extremities. Near the shoulder or hip joint there are probably none, except possibly Berger's case, at the upper end of the humerus, reported by Jeanbreau and Riche.[10]

I have examined in some detail the statistical reports of Kocher, Coley, Reinhardt, Butlin, Nasse, and others, and have been unable to draw any definite conclusions from them, because of the uncertainty in diagnosis. Greenough, Simmons, and Harmer, however, carefully classify fifty-six cases of true osteogenic sarcoma occurring at the Massachusetts General and the Huntington hospitals, and report three cures of three years' standing by radical operation. These tumors were located in the femur, tibia, and inferior maxilla, and all were of highly fibrous or ossifying structure. On the other hand, barring one operative death in a very extensive case, all of the fourteen patients with giant cell tumors were cured by operation.

10. Jeanbreau and Riche: Rev. de chir. **32**:153, 1905.

More significant than combined statistics is the analysis of the types of cases for which amputation may reasonably be expected to yield success. All the cellular and vascular sarcomas treated surgically seem to have been fatal within a few months. Likewise the established small spindle cell periosteal sarcomas are extremely malignant.

More favorable conditions are furnished in the very early stages of sclerosing central and subperiosteal tumors which have not ruptured the periosteum. For such tumors prompt amputation may well be endorsed as offering a reasonable hope of success, although the attested records of such success are extremely rare. More favorable still are the encapsulated fibrosarcomas attached to the periosteum. Many of these growths are comparatively acellular and are at first capable only of local recurrence. They form a considerable proportion of the reported surgical cures.

With the use of physical agents as adjuvants to surgery, they form a favorable field for conservative surgery, aiming at local extirpation followed by treatment by roentgen ray or radium. As long ago as 1908, Goebel [11] reported the cure (fifteen months' observation) of a malignant infiltrating periosteal sarcoma of the femur in an infant in whom he twice extirpated portions of the tumor and followed the operations with exposure to the roentgen ray to the limit of skin tolerance.

In order to secure more accurate data regarding the prognosis of osteogenic sarcoma, the following scheme may be offered as indicating the different grades of malignancy in the disease; and it is suggested that the use of some such scheme replace the custom of merging all types of osteogenic sarcoma in statistical reports.

1. Encapsulated extraperiosteal fibrosarcoma; fibrous, cartilaginous or osteoid stroma in excess of cells; prognosis fair.

2. Sclerosing medullary and periosteal sarcoma; course slow; metastases appear very late.

3. Cellular spindle cell periosteal sarcoma; stroma scanty or absent; some cures by surgery and other methods.

4. Solid cellular central and subperiosteal sarcoma; some surgical cures of early cases.

5. Very vascular cellular telangiectatic sarcoma; no reported cures.

For the past seven years, I have been interested in efforts to control osteogenic sarcoma by physical agents at the Memorial Hospital. The results have been unsatisfactory but encouraging. They involve many clinical and technical considerations that belong to my clinical and radiologic colleagues. My own services have been directed toward securing accurate anatomic and histologic diagnoses, and to the study

11. Goebel: Arch. f. klin. chir. **87**:191, 1908.

of the effects of the physical agents on the tissues. From these sources of information the following conclusions have been drawn.

1. It has been shown by physical computation, histologic changes in the tumor tissues, and clinical results, that it is possible to deliver an effective dosage of roentgen ray or radium to all parts of many osteogenic sarcomas where the tumors are accessible from all sides.

2. The histologic changes demonstrate a slowing of the rate of growth of the tumor cells, by which they are induced to lay down calcific material, or dense hyaline stroma, or bone. With vascular and cellular tumors, hemorrhage and necrosis may be produced.

3. Cellular tumors without much intercellular stroma may undergo complete resolution and disappear.

In evidence of this statement I would refer to the following case:

In 1915, Dr. C. H. Peck referred to the hospital a boy, aged 8 years, with a recurrent periosteal sarcoma of the metacarpal bone of the thumb. The tumor had recurred promptly after excision, presenting a globular swelling, 2 by 3 cm. Section of the original tumor showed a small spindle cell sarcoma without demonstrable stroma. Roentgen-ray treatment (Müller tube), given by Dr. Arthur Holding for three months, produced, for the first month, no definite effect; during the second month, the tumor ceased to grow; after the fourth month, there was steady recession, which became complete in six months. The boy was followed for four years without recurrence.

4. Tumors producing much intercellular material can probably not be made to disappear by present technic with physical agents. The most that can be hoped for such tumors is the sclerosis or ossification of the tumor tissue with cessation of growth.

5. The majority of true osteogenic sarcomas under radiation, while suffering retardation of growth, prove fatal from the usual metastases. It may be said that they would do so under any circumstances; but the possibility that prompt amputation might save some patients may be considered by many as a bar to conservative treatment. On the other hand, the long survival of certain cases heavily radiated and later coming to amputation strongly suggests that effective radiation distinctly postpones metastases.

6. The technic of employing roentgen ray and radium in osteogenic sarcoma can be made much more efficient by the proper selection of cases, by more careful study of the exact anatomic condition to be dealt with, adapting the agents to the conditions as found, and by a judicious combination with surgery.

It is obvious that the problems here involved are of a major character and demand the most intelligent cooperation of surgeon, radiologist and pathologist. From results already obtained I am convinced that large rewards await the resourceful worker, by using all the means now at his disposal, in reducing the mortality from this lethal disease.

THE GENERALIZED TYPE OF OSTEITIS FIBROSA CYSTICA

VON RECKLINGHAUSEN'S DISEASE *

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INTRODUCTION

The localized form of osteitis fibrosa, especially in its relation to the formation of bone cysts, has been very commonly recognized and commented upon during the last twenty years. Bloodgood,[1] in numerous publications, and also Barrie,[2] Silver,[3] and Meyerding,[4] have furnished valuable contributions to the American literature; and Elmslie [5] has given a good summary of the English cases. The Germans have written at length on the subject.

The generalized type, however, has received scant attention, possibly because it is not recognized; and, aside from the article by Lötsch,[6] no extensive publication has been devoted entirely to this form of the disease, although both Meyerding and Elmslie discuss the generalized cases in their papers.

It seemed worth while, therefore, to report the subjoined case: first, because of the rarity of the condition, especially in the United States, and secondly, because of the possibility of correcting some of the deformities arising in this disease. At the same time, it was considered advisable to collect the reports of general types of the disease in order to find what might be learned from them.

REPORT OF CASE

History.—A man, aged 23, a lathe operator, was referred, Nov. 14, 1919, by Dr. Stanley Cox of Holyoke, Mass., complaining of bowing of the thigh bones. Except for the usual children's diseases, the history was essentially negative. He had never had a serious illness, although he had had a sore

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* I am indebted to Dr. Robert W. Lovett of Boston for permission to use his records of the case reported in this article.

1. Bloodgood, J. C.: Bone Cysts, J. A. M. A. **43**:1124-1129 (Oct. 15) 1904; Prog. Med. **5**:188-192, 200-204 (Dec.) 1903; ibid. **6**:181-194 (Dec.) 1904; ibid. **7**:273-280 (Dec.) 1905; Ann. Surg. **12**:145-189, 1910.
2. Barrie, G.: Ann. Surg. **61**:128-142, 1915; ibid. **67**:354-363 (March) 1918.
3. Silver, D.: Am. J. Orthop. Surg. **9**:563-588, 1911-1912.
4. Meyerding, H. W.: Am. J. Orthop. Surg. **16**:253-276 (Sept.) 1918; ibid. **16**:367-382 (Oct.) 1918.
5. Elmslie, R. C.: Brit. J. Surg. **2**:17-67, 1914.
6. Lötsch, F.: Arch. f. klin. Chir. **107**:1-137, 1915.

throat occasionally and frequent colds but no cough. His appetite was good; the bowel movements regular, and he denied venereal infection. Three years previously, he had an attack of facial erysipelas, lasting about three weeks. At 3 years, he fell and fractured the right femur. Union was good under ordinary treatment. At 4 years, the right arm was hit by a swing and broken

Fig. 1.—Three views of patient showing marked bowing of the femurs with shortening of the right leg and equinus position of the right foot.

just above the wrist. He had no further trouble in any way until he was 12 years old. At that time he fell, after which he could not walk for two or three days. It was six or seven weeks before the pain and limp disappeared. At 16, he fell over a railroad track and again broke the right femur. He was

in the hospital six weeks; and the fracture united without complication. He had no trouble during the subsequent five years, until March, 1919, when he began to have pain just above the right knee, which gradually became more severe. Some days he could not get up from his chair because of inability to extend the leg at the knee. This continued until July, 1919. At that time he suffered with pain in the left knee, which extended up the thigh into the hip, and the pain in the right thigh disappeared. The upper portion of the left thigh became bent and a roentgenogram showed a pathologic lesion of the bone. July 21, 1919, while walking, his left foot hit against a clump of grass, tripping him. He fractured the left femur by this fall and was in the hospital eleven weeks. The bowing of the femur was considerably reduced by the

Fig. 2.—Defects in the frontal and occipital regions.

treatment of this fracture. In October, 1919, there was a return of pain in the right thigh and knee, which had persisted to the time of examination. The pain was not severe, did not keep him awake, but was annoying and "rheumatic-like." He walked with a limp on the right side and with the aid of a cane.

Examination.—The patient was well developed and well nourished. There was no apparent pain at the time of examination. No abnormalities were noted in the head. The sinuses were not tender on pressure. The pupils were equal; reacted to light and on accommodation. There was no nystagmus. The von Graefe sign was not elicited. There was no exophthalmos. The extra-ocular movements and the eye grounds were normal. There was no mastoid tenderness; no

discharge from the ears and no defect in hearing. Breathing was partially obstructed on both sides of the nose. The mucous membranes of the mouth were of normal color; the tongue protruded in the midline and was clean. The teeth were in bad shape; many were missing, and there were a number of old snags in the molar region of the upper and lower jaws. The tonsils were embedded and somewhat scarred. There was no general glandular enlargement. The epitrochlears were not palpable. The thyroid was not enlarged. There was no tremor and no tachycardia.

Fig. 3.—Defects in left frontal region.

The chest was not quite symmetrical, being somewhat depressed below the precordial region and the ribs flared slightly laterally. The percussion note and vocal fremitus were normal. There were no râles. The heart was normal in position and size. The sounds were regular and clear. No murmurs were heard. The heart rate was 70. The pulses were equal and of good volume and tension. No tenderness and no masses were detected in the abdomen on palpation. No organs were palpable. Rectal examination was negative. The genitalia were normal. The spine showed no scoliosis. Movements of flexion, extension, side bending and rotation were normal. There was no disturbance

in the range of motion of any of the joints, except the hip and knee. The reflexes were present and equal in the arms and legs on both sides. Sensation was normal throughout.

Both thighs showed a very marked outward bowing, especially the right (Fig. 1 *A*). This deformity had shortened the distance between the gluteal fold and the knee joint on the right side to such an extent that the patient could not get his right heel to the floor (Fig. 1 *B* and *C*). The deformity was mainly of the thigh bones, which palpation demonstrated to be considerably thickened. The trochanters were high above Nélaton's line and were also

Fig. 4.—Beginning changes in the upper humerus and at the junction of the upper and middle thirds.

thickened. There was practically no abduction in either hip; adduction was normal; flexion to a right angle was possible on both sides; there was no rotation of either hip. The knee joints flexed to about 75 degrees; extension was complete.

Measurements were: the anterior superior spine to the malleolus (left) 35 inches (89 cm.); the anterior superior spine to the malleolus (right) 33 inches (83.8 cm.); the umbilicus to the malleolus (left) 38 inches (96.5 cm.); the umbilicus to the malleolus (right) 36 inches (91.5 cm.).

Tibia measurements were: malleolus to tibia tubercle (left) 14 inches (35.5 cm.); malleolus to tibia tubercle (right) 15 inches (38 cm.).

Femur measurements were: anterior superior spine to tibia tubercle (left) 21 inches (53.3 cm.); anterior superior spine to tibia tubercle (right) 18 inches (45.7 cm.).

Circumference measurements were: thigh (left) 18 inches (45.7 cm.); thigh (right) 18½ inches (47 cm.); calf (left) 13½ inches (34.3 cm.); calf (right) 11¾ inches (31.3 cm.).

Figure 5

Figure 6

Fig. 5.—Changes in the upper end of the right radius and ulna showing areas of rarefaction and thinned cortical bone.

Fig. 6.—Right femur showing marked bowing and coxa vara, foamy cystic appearance of bone, no differentiation between cortical and medullary bone and a fracture of the midshaft. Compare with Figure 14, one of von Recklinghausen's original cases.

Special Examinations.—Urine: The color was high; the specific gravity was 1.026. The slightest possible trace of albumin was demonstrated by heat test.

No positive result was obtained with nitric acid; no sugar was present. No Bence-Jones bodies were found on three examinations. There were many calcium oxalate crystals.

Stool: There was no abnormal gas formation and no abnormal odor. The reaction was neutral and smears were microscopically negative.

Blood: One c.c. of venous blood in a tube of 9 mm. diameter clotted in five minutes. This may be looked upon as the lowest limit of normal clotting time. The clot retracted normally and the blood serum contained no abnormal pigments. Hemoglobin was 80 per cent. plus. The red cells showed no abnormal variation in size. They were perhaps slightly achromic. No polychromatophilia was present, nor were any other abnormalities noted. Platelets occurred in normal numbers and appeared of normal character. White cells, as estimated from blood smears, numbered about 6,000. The differential count was: poly-

Fig. 7.—Both femurs involved, the right more than the left, the process differing only in degree.

morphonuclear neutrophils, 64 per cent.; lymphocytes, 30 per cent., and large mononuclears, 6 per cent. The white cells were of normal character. No eosinophils or basophils were seen. The blood was entirely normal except for a trifling secondary anemia. There was no evidence of any disturbed bone marrow or hematopoietic function. The Wassermann reaction was negative.

Roentgen-Ray Examination.—Roentgenograms were taken of practically all the bones in the body and the following condition was noted: The periosteum of the cranial bones was of normal appearance; the cortical bone was not thickened; but scattered through its substance were clear spaces, especially marked in the frontal and occipital regions. These spaces were from pinhead to pea size and were surrounded by a slightly denser shadow. The sinuses

were unchanged and the bones of the face showed nothing abnormal (Figs. 2 and 3). The vertebral column showed nothing worthy of note. The clavicles, scapulae, ribs and iliac bones were normal. The right humerus showed at the junction of the upper and middle thirds unmistakable early evidence of the disease process. Here the cortical bone presented a thinning and spongy cystic formation, with slight reaction about the clear spaces. The periosteum was unchanged, and there was no deformity of the bone (Fig. 4). The right forearm showed beginning changes in the upper third of the radius and ulna, very

Fig. 8.—Thinning of cortical bone in the fibula; also large cystic patch in the upper end of the tibia and scattered small areas of rarefaction.

similar in appearance to those observed in the humerus (Fig. 5). The bones of the right wrist and right hand were practically without change. Small areas of rarefaction occurred in the basal phalanx of the thumb, and in the middle phalanx of the index finger.

The left arm was not examined roentgenographically. The right femur was the bone most involved in the disease process. It resembled the shepherd's crook referred to by von Recklinghausen. The whole bone was markedly bowed

outward, especially in its upper and middle portions. It was considerably expanded in width throughout its entire length. The head seemed to be of normal appearance, smooth in the joint cavity, with no signs of trouble. The great trochanter impinged upon the iliac bone above the rim of the acetabulum. The neck showed a very marked coxa vara. The periosteum of the bone was apparently unchanged. The cortical bone was riddled throughout the entire shaft with areas of honey-combed, foamy looking spaces, in places sharply

Fig. 9.—Right foot with occasional small calcium poor areas, showing distinctly the cysts of the tibia and thinning of the cortical bone of the fibula.

outlined, in others merging in long streaky lines. There was no medullary cavity apparent, the whole area being filled with the spongy substance mentioned above. There was a thickening of the cortical bone on the concavity of the curve. At about midshaft on the convexity was a beginning fracture with considerable separation of the outer portions (Fig. 6). The left femur resembled

the right in practically every detail of structure. It differed only in the lessened degree of the bowing and the coxa vara, and in the less marked evidence of the disease. There was a healed fracture in the midshaft which showed a heaping up of periosteal callus and very little deposit of lime. Both femurs showed considerable diminution in the lime content (Fig. 7). The knee joint on the right showed no involvement. The right tibia showed considerable evidence of disease throughout its entire shaft. Areas of thinning of

Fig. 10.—Left foot and leg bones showing diffuse mottled shadows and in places very thin corticalis.

the cortex occurred, in places only a thin shell of periosteum remaining. The medullary cavity was indistinct and merged with the cortical mottled shadow. The right fibula was much less involved but showed the beginning disease in spots. The cortex and medulla remained indistinct throughout most of its length (Fig. 8). The right foot was relatively free, though an occasional

rarefaction was visible on close study of the bones (Fig. 9). The left tibia and fibula were similar in appearance to the right leg bones, and the bones of the left foot were not extensively involved (Fig. 10).

Treatment.—A plaster spica was applied to the right femur, and an attempt was made to wedge the bone over. This was considered worthy of trial, because there was a separated fracture line at the midshaft, and it was thought that the bone was plastic. This line of attack was not very successful, however,

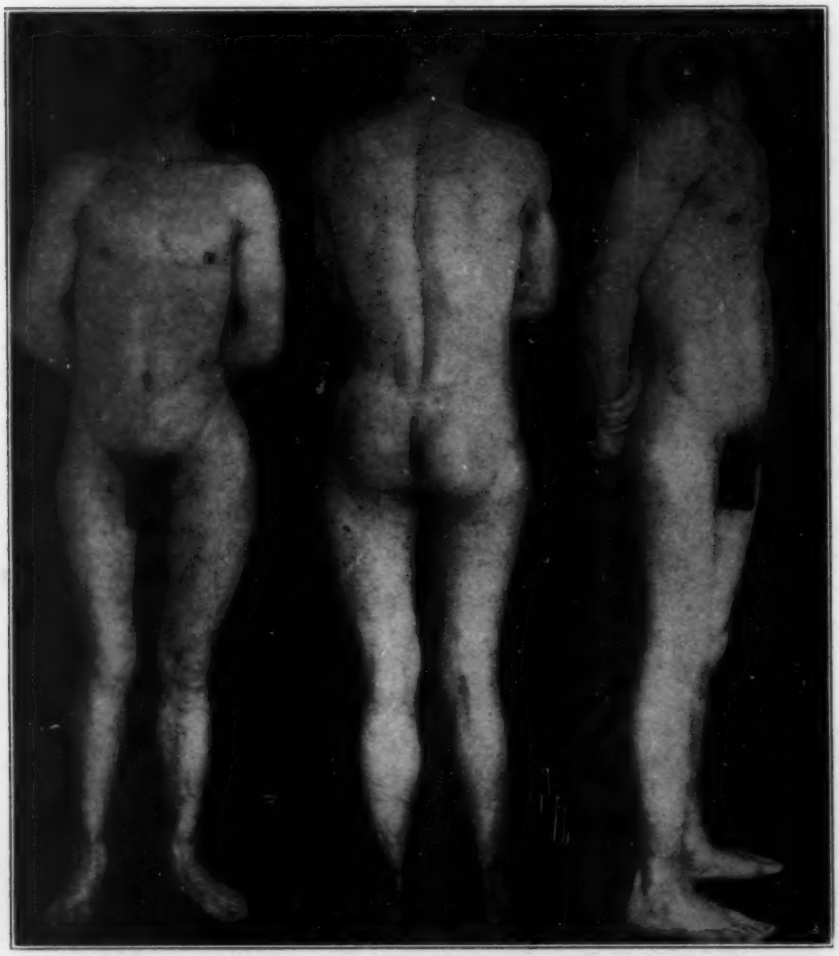

Fig. 11.—Patient after operation; the right femur is much straighter and he can put his heel on the ground easily.

so, Jan. 5, 1920, an open wedge-shaped osteotomy was performed in the upper third of the shaft. The periosteum appeared normal and stripped back easily. The cortical bone was vascular and relatively soft in consistency on the convexity of the curve; but it was necessary to use a mallet to drive the osteotome through it. No definite medullary cavity was made out. The concavity of the curve

was decidedly harder and quite difficult to cut through with the osteotome. The incision was sutured with fine silk and the leg was put up in extension in a Thomas splint. The postoperative course was uneventful. The femur was considerably straightened in its upper portion by this operation. Healing was solid in four weeks. The patient was discharged in a plaster hip spica which he wore for about three months.

He reported in October, 1920, for a second osteotomy to be performed on the lower part of the curved femur. This operation was performed under ether, Oct. 19, 1920. The periosteum was not thickened in the lower third of

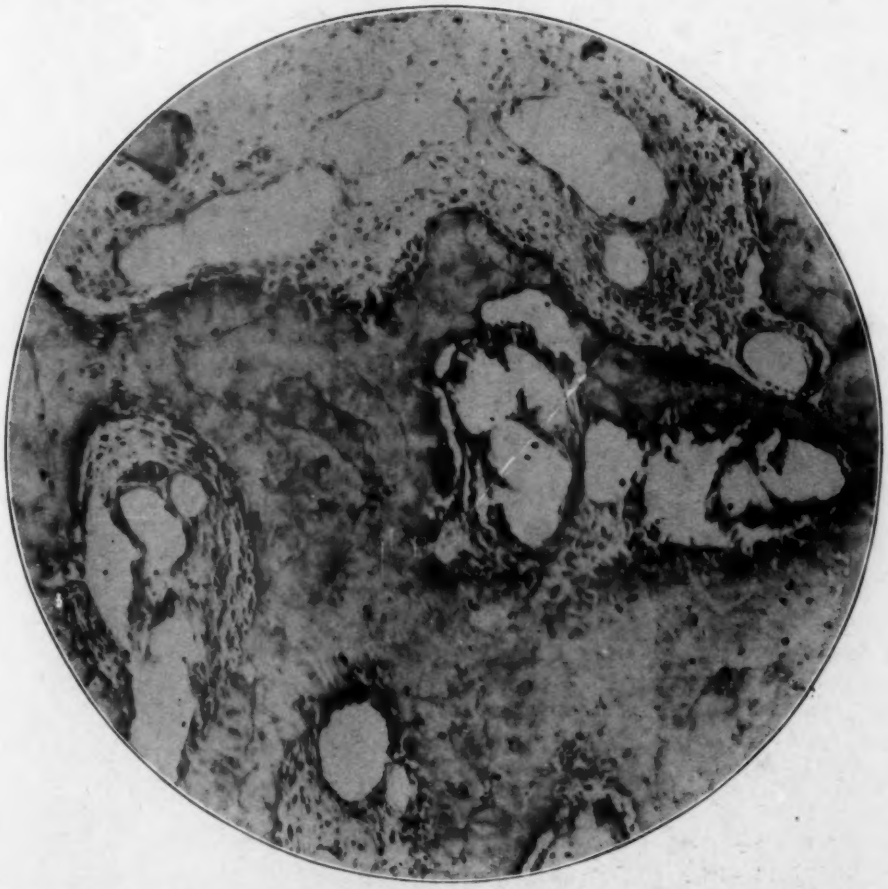

Fig. 12.—Low power photomicrograph of specimen removed at operation, showing infiltration of connective tissue, replacing the bony trabeculae, the formation of small cystic spaces in the connective tissue and the scattered osteoclast giant cells.

the shaft; the cortical bone was fairly soft and vascular. There was a more apparent medullary cavity in this portion of the bone. The wound was closed with fine silk and the leg was put in a plaster cast. Convalescence was uneventful. He was discharged in a cast, Oct. 30, 1920. A roentgenogram was taken the day of discharge showing the bone alinement to be good.

A roentgenogram, taken Nov. 18, 1920, showed the bones in good position with considerable callus formation. The cast was removed Feb. 23, 1921, and baking and massage of the knee joint were started. Measurements on this date were: right, anterior superior spine to malleolus, 35½ inches (90 cm.); left, anterior superior spine to malleolus, 35 inches (89 cm.); right, umbilicus to malleolus, 37 inches (94 cm.); left, umbilicus to malleolus, 37 inches (94 cm.). He put the whole foot on the floor easily and walked without difficulty (Fig. 11). He wrote in May, 1921, that he was getting about perfectly on his leg and that

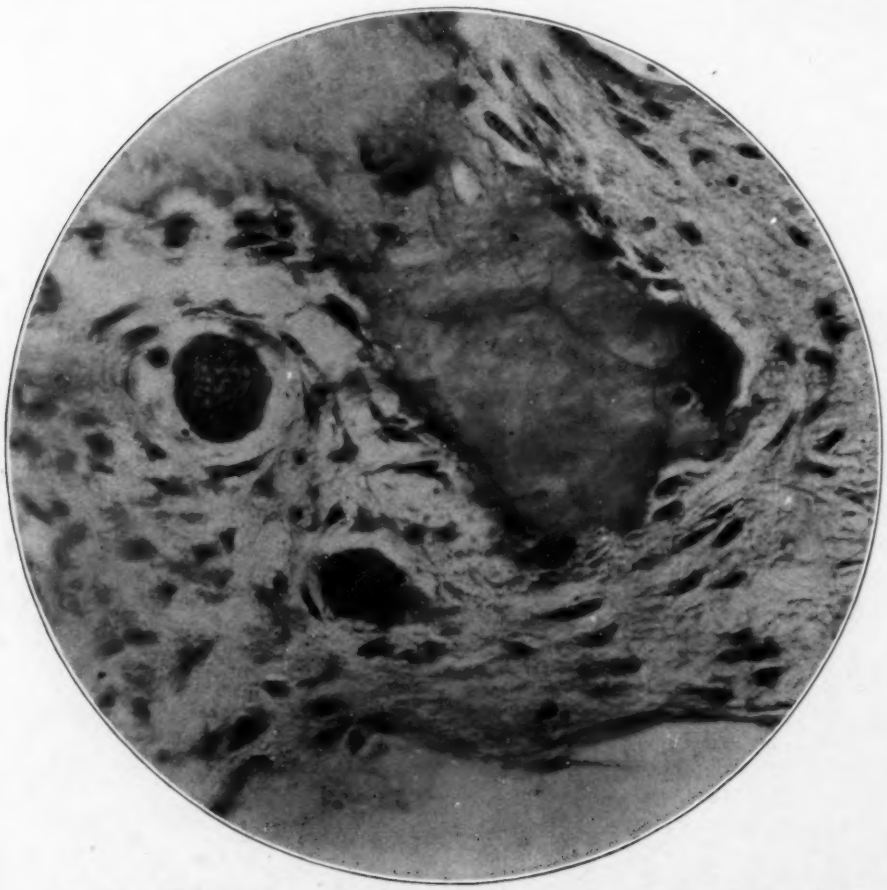

Fig. 13.—High power photomicrograph showing two giant cell osteoclasts, fibroblasts of the connective tissue and a blood vessel in the left center.

it was as good as new. The knee joint was entirely free in its motion and he had returned to his occupation.

Pathologic Report.—The specimen removed at the first operation was examined by Dr. V. C. Jacobson of the Peter Bent Brigham Hospital, Pathological Department, to whom my thanks are due for the photomicrographs and for the following report: "There are three sections showing the same picture. The tissue is composed of narrow anastomosing trabeculae of bone, much in the nature of cancellous bone, separated by large spaces, irregular in shape,

some rather cystic, usually quite filled with a loose reticulum in which lie more or less spindle-shaped cells, resembling fibroblasts. These cells form a large part of the nonbony part of the tissue and are closely packed along the bone trabeculae, where osteoblasts are also present in moderate numbers. Fat is still present in these areas, but in small amount and it appears to be replaced by the spindle cell growth. A few small capillaries ramify in these spaces and hemorrhage is seen to have occurred often. The bone is all of periosteal origin and the condition is fairly typical of osteitis fibrosa" (Figs. 12 and 13).

Diagnosis: "Osteitis fibrosa."

Cultures: "Cultures of the specimens taken at each operation failed to show any growth on aerobic or anaerobic culture media."

HISTORICAL REVIEW

Hirschberg,[7] in 1886, is usually credited with having given the first description of the generalized type of the condition under discussion, although he did not recognize it as a separate entity but thought that it was a form of osteomalacia. Von Recklinghausen[8] followed him five years later (1891) with the report of three cases which he considered as differing from the commonly recognized types of bone lesions and proposed the name "osteitis fibrosa cystica," this describing what he believed at that time to be the pathologic process. In 1910 the same author in an extensive work, "Untersuchungen über Rachitis und Osteomalacia," reviewed the literature and classified as this disease a few cases which were described as osteomalacia with tumors and cysts a number of years previous to the appearance of Hirschberg's article. Thus the reports of Froriep,[9] 1840, and of Engel,[10] in 1864, and of Langendorff and Mommsen,[11] 1875, were all included in von Recklinghausen's latest classification under the term "metaplastic malacia." Sporadic reports have appeared in the thirty years following von Recklinghausen's original description and the total of the recorded cases of the general type, excluding the few transitional cases in which only two bones have been involved (Bockenheimer,[12] Tietze,[13] Röpke,[14] Pfeiffer,[15] Körte,[16] R. Johnson,[17] etc.) is still very small. Ringel,[18] in

7. Hirschberg, K.: Beitr. z. path. Anat. u. z. allg. Path. **6**:513-524, 1889.

8. Von Recklinghausen, F.: Festschr. Rudolf Virchow, 1891; Untersuchungen über Rachitis und Osteomalacia, 1910.

9. Froriep: Chir. Kupfertafeln, Weimar, **9**: 1838-1842.

10. Engel: Inaug. Dissert., Giessen, 1864.

11. Langendorff, O., and Mommsen, J.: Arch. f. path. Anat. **69**:452-486, 1877.

12. Bockenheimer, P.: Arch. f. klin. Chir. **81**:236-274, 1906.

13. Tietze, A.: Beitr. z. klin. Chir. **52**:495-559, 1906; Verhandl. d. deutsch. Gesellsch. f. Chir. **35**:167-171, 1906.

14. Röpke, W.: Arch. f. klin. Chir. **92**:126-154, 1910.

15. Pfeiffer, C.: Beitr. z. klin. Chir. **53**:473-495, 1907.

16. Körte, W.: Verhandl. d. deutsch. Gesellsch. f. Chir. **35**:194, 1906; Deutsch. Ztschr. f. Chir. **13**:42-50, 1880.

17. Johnson, R., Cited by Elmslie: Reference 5, p. 44.

18. Ringel: Deutsch. med. Wchnschr. **44**:367, 1918.

Fig. 14.—Femur and ulna from Case 5 in von Recklinghausen's original paper, 1891. The femur shows the characteristic bowing and the "shepherd's crooking" of the neck and head; a large cyst in the shaft and white connective tissue replace the bone; the ulna shows three cysts and fibrosis.

Fig. 15.—Skeleton of Case 6 in von Recklinghausen's original paper, 1891, showing characteristic skeletal deformities.

1918, asserted that there are about thirty cases known, and Roth,[19] in 1920, that there are only forty. Barrie,[20] writing in the *Annals of Surgery,* in 1920, asserted that there have been but four cases of patients with multiple giant cell sarcoma reported in the American literature, although cases without giant cell tumors are more numerous.

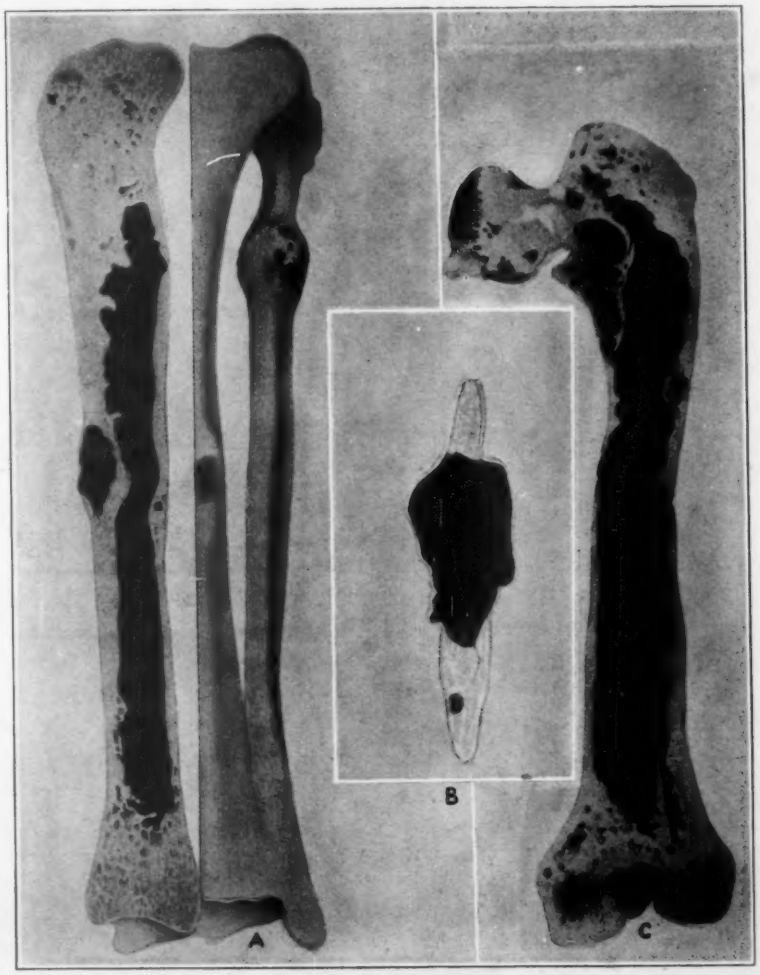

Fig. 16 (Case 7 in von Recklinghausen's article, 1891).—A, tibia and fibula with giant cell tumors; B, cyst in giant cell tumor of a rib, and C, femur showing giant cell tumors near lesser trochanter and smaller ones in shaft, also a fracture line through the midshaft.

19. Roth, M., and Volkmann, J.: Mitt. a. d. Grenzgeb. d. Med. u. Chir. **32**:427-453, 1920.

20. Barrie, G.: Ann. Surg. **71**:581-593 (May) 1920.

CLASSIFICATION OF TYPES

On reviewing the literature it becomes at once apparent that there are several different types or stages of the disease which have been described by various authors. There are certainly two outspoken groups, namely the cases with so-called giant cell sarcoma (myeloid sarcoma, giant cell tumor, hemorrhagic osteomyelitis, etc.); and those in which giant cell sarcomatous masses are not present. Fibrosis is a factor common to both groups and cyst formation is almost always present; but further subdivision is possible if cases are considered with regard to the occurrence of general malacia of the skeleton or hyperostosis of a portion of it. It is difficult to make a rigid classification as there is so much individual variation and overlapping from one variety to the other; but in general it is possible to group the cases according to the following scheme:

Group 1.—Without giant cell sarcoma:

A. With multiple cysts, fibrosis and malacia confined to a few bones.

B 1. With multiple cysts, fibrosis and predominant general malacia.

B 2. With multiple cysts, fibrosis, general malacia and hyperostosis.

Group 2.—With giant cell sarcoma:

A. With cysts, fibrosis and tumors, but no marked malacia.

B 1. With cysts, fibrosis and tumors, and marked malacia.

B 2. With cysts, fibrosis, tumors, malacia and hyperostosis.

The majority of the cases fall into Group 1; and it has been possible to find 37 in the literature. Of these, 22 fall into subdivision A; and 8 and 7 fall into subdivisions B 1 and B 2, respectively. In Group 2 there are 26 cases, the greatest number of which fall into subdivision B 1, 16; the other 10 cases being about equally divided between A and B 2.

Group 1 (A) is characterized by the fact that the disease occurs most often in young people, sixteen of the patients being under 30 years of age. If the first evidence of the process is taken into account, it is apparent that the onset is frequently in early childhood. In the accompanying table showing the subdivision, the earliest symptom which could be considered as referring to the disease has been taken as the onset of the process. In this way the origin of many of the cases can be traced back to the first 10 years of life. Burchard [21] has roentgen-ray proofs of cyst formation in his case at 18 months, and Bradfield [22] at 6 years. The oldest patients reported in this subdivision are 59 and 51 years of age; and there is evidence that the process in

21. Burchard, A.: Fortschr. a. d. Geb. d. Röntgenstr. **19**:113, 1912.

22. Bradfield, Cited by Elmslie: Reference 5, pp. 56-57.

TABLE I.—Cases in Group I (A) *

Case	Age	Sex	Cysts	Malacia	Duration	Symptoms	Treatment	Result	Pathologic Report
Barrie (Case 1915)	12	♂	Left femur; left pelvic bone; left fibula	Left femur	Since 5 years of age	Fracture	Osteotomy for deformity	Good	None
Barrie (Case 1918)	32	♂	Femurs; tibias; fibulas (small)	Not marked	Since 10 years of age	Pain	Medical	Good	None
Bradfield	6	♂	Humeri; femurs; left tibia	Both femurs bowed	Since 6 years of age	Fracture	Splinting	Good	None
Burchard	4	♂	Right femur; right tibia; right fibula	Femurs bowed	Since 1½ years of age	Limp	None	Good	No examination
Hamann[23]	23	♂	Both zygomatic bones; tibias	.....	Since 22 years of age	Swelling; pain	Hypophysis feeding	Good	No examination
Harting[24]	34	♂	Right ulna; right femur; tibias; humeri; clavicles, etc.	Not marked	Since 33 years of age	Fracture; pain	Cyst tapped	Good	None
Heineke[25]	24	♀	Femurs; left tibia; iliacs; right humerus, left great toe	Local only	Since 4 years of age	Fracture; pain	Osteotomy; exploration of cyst	Good	Fibrous marrow; cysts
Martin[26]	17	♂	Skull; dorsal vertebrae; humeri; femurs; leg bones	Right femur	Since early childhood	Fracture; pain; limp	Osteotomy	Good	Fibrous marrow, osteoid; malacia
Meyerding (Case 13)	17	♂	Right femur; right tibia; right fibula	Femur markedly bowed	Since 12 years of age	Fractures; malunion	Excision; bone graft	Good	Osteitis fibrosa cystica
Meyerding (Case 14)	21	♀	Right frontal; right radius; right humerus; right tibia; right fibula; right femur	Local only	Since 6 years of age	Fracture; tumor	Resection radius head, curetting and crushing in of tibia	Good	Osteitis fibrosa cystica
Meyerding (Case 15)	29	♂	Right humerus; both femurs; both tibias; both fibulas	Local only	Since 10 years of age	Fracture; nonunion	Excision; extension; bone graft	Good	Osteitis fibrosa cystica
Meyerding (Case 16)	26	♂	Left femur; left tibia; left fibula; left humerus	Local only	Since 12 years of age	Fracture; malunion	Excision; extension; bone graft	Good	Osteitis fibrosa cystica
Meyerding (Case 17)	30	♀	Both humeri; upper end of radius	Local only	?	Fracture	None	Good	No examination
Meyerding (Case 18)	19	♂	Fifth metacarpal of fourth and fifth fingers	Local only	Since 6 years of age	Swelling of right hand	Crushing of cyst walls	Good	No examination
Meyerding (Case 19)	41	♀	All the long bones	Local only	Possibly since 26 yrs. of age	Pain; swelling	Operation advised	Good	Section nonmalignant
Von Mickulicz[27]	?	?	Both femurs; radius; tibia	No	No details given				
Moll[28] (Case 1)	30	♀	Humeri; radii; ulnas; pelvic bones	Spine?	Since 41 years of age	Pain; limp; fracture	Extension	Good	None
Moll[28] (Case 2)	29	♀	Skull; right humerus; two left ribs; right femur; right tibia, etc.	Spine?, both tibias	Since 24 years of age	Pain; fracture	Operation; left tibia; cyst eradicated	Good	Fibrous marrow, osteoid
Morton	22	♂	General	Both femurs bowed	Since 3 years of age	Pain; fracture	Osteotomy for deformity	Good	Fibrous marrow, cysts
Ringel	20	♂	All the pipe bones and ribs	Local only	?	Fracture	Splinting	Good	No examination
Roth and Volkmann	51	♀	Tibias; left fibula; right radius; right femur; ribs; hands	Not marked	Since 41 years of age	Swelling; pain; fracture	Exploratory operation tibia	Good	Fibrosis osteoid
Wehner[29]	21	♀	Left radius; right scapula; left pelvis; calcanei cuboid, etc.	Both femurs	Since 3½ years of age	Pain; fracture	Not stated	Good	None

* In this and the following tables, ♂ indicates male and ♀, female.

23. Hamann, O.: Med. Klin. **16**: 63-64 (Jan.) 1920.
24. Harting, A.: Am. J. Roentgenol. **1**: 203-208 (March) 1914.
25. Heineke, H.: Beitr. z. klin. Chir. **40**: 481-498, 1903.
26. Martin, B.: Berl. klin. Wchnschr. **56**: 355-356 (April) 1919.
27. Von Mickulicz: Centralbl. f. Chir. **31**: 1323, 1904 (Discussed by Von Haberer).
28. Moll, K.: Beitr. z. klin. Chir. **118**: 433-445, 1920.
29. Wehner, E.: Fortschr. a. d. Geb. d. Röntgenstr. **27**: 140-144, 1919-1920.

each of these is ten years, or more, old. In general, the course is chronic and runs for years without change in its character. The most common manifestation of the disease is fracture, this leading to its discovery in most instances; other signs are bowing of the bones and tumor. Pain is sometimes a complaint and is usually of a rheumatic nature. The bones most frequently attacked are the pipe bones of the lower extremities, although the upper extremity is by no means spared. Cysts of the skull and ribs occur but not commonly. The bowing of the femurs is practically the only sign of malacia in these cases. The prognosis is good as to life; no fatalities being recorded for this group. The fractures heal well if properly treated; the patients stand operation well and the bone reacts to operation much the same as normal bone. Deformity is amenable to correction. The diagnosis is made from the roentgen-ray appearances, and microscopic section shows marrow fibrosis and numerous cysts with here and there a giant cell. Many of this group have not had a pathologic examination but have been classified here because they most nearly conform to the type.

In contradistinction to subdivision A, the cases recorded under B 1 seem to offer a very poor prognosis, ending in almost every instance in death. There are but few cases recorded from which to draw any definite conclusions; but of these all but one occurred in the female. Most of them are reported at a later age; and there is nothing to indicate a long chronicity from early years. Two cases reported by Joachimsthal [30] and Meslay [31] are exceptions to the last statement. The predominant character of the process is a genereal softening of the whole osseous system, a true osteomalacia, indistinguishable clinically from the puerperal form of that disease; in fact, all of these cases were reported by the various authors as the nonpuerperal type of osteomalacia. Von Recklinghausen has picked them out and classified them purely from the pathologic picture presented at necropsy. The symptoms given by this form are marked pain, numerous fractures, rapidly increasing deformity and helplessness, so that the patients all become bedridden in a short time and remain in a pitiful condition to the end. The course is downhill within a few years, with anemia and emaciation as accompanying evidence of the severity of the process. No treatment known appears to affect the progress of the malady. Diagnosis is made from the pathologic finding of a metaplastic picture in the diseased bones, a marrow fibrosis and cystic formation in addition to the halisteresis or calcium withdrawal.

Subdivision B 2 is practically identical with the preceding in every respect, except for the occurrence of hyperostoses of certain bones, notably the skull, making it difficult to differentiate the condition from

30. Joachimsthal: Verhandl. d. Gesellsch. d. charité Aertze **17:** 1911.
31. Meslay: Thèse de Paris, 1896; Rev. mens. d. mal. d. l'enf. **15:** 1897.

TABLE 2.—Cases in Group 1 (B 1)

Case	Age	Sex	Cysts	Malacia	Duration	Symptoms	Treatment	Result	Pathologic Report
Albertin[32]	35	♀	Right humerus; both femurs; both iliac bones	Whole skeleton	Not observed clinically	.....	.....	Death	Fibrous marrow; cyst formation; malacia
Bramann[33]	34	♀	Both femurs; both tibia; left radius	Ribs; vertebrae; pelvis; both tibias, etc.	Since 30 years of age	Pain; deformity; fracture	Bed	Death; stomach catarrh; jaundice	Fibrous marrow; cysts- osteoid; numerous giant cells
Engel	55	♀	Pelvic bones; both humeri; both femurs; all vertebrae; both scapulas; both clavicles; sternum; ribs; right radius; jaw; few bones of hands and feet	General	Since 42 years of age	Pain; deformty; fractures	Bed	Death; pneumonia; pleurisy; anasarca	Fibrous marrow; cysts; malacia
Joachimsthal	13	♀	Both humeri; both ulnas; both radii; both scapulas; both clavicles; metacarpals; phalanges; most of ribs; pelvis; left fibula; left femur; tibia	Bones of extremities; left ribs	Since 6 years of age	Fracture; deformity	.....	Not stated	No examination
Koehl-Hanau[34]	48	♀	?.....	Femur; lumbar vertebrae	Since 46 years of age	Fracture; swelling of legs; pain	Bed	Death; ileus	Fibrous marrow; osteoid; a few giant cells; malacia
Langendorff and Mommsen	33	♂	Left humerus; left tibia; left fibula	General	Since 32 years of age; rickets as a boy	Pain; fracture; deformity	None	Death; asphyxia	Fibrous marrow; cysts; malacia; giant cells
Meslay	15	♀	?.....	Pipe bones; thorax; vertebrae	Since 13 years of age	Pain; fracture; deformity	Early osteotomy	Death; cause ?	Fibrous marrow; osteoid; malacia
Saxinger[35]	36	♀	Right tibia; left tibia; right femur; right forearm; left humerus	Vertebrae; ribs; pipe bones	Since 33 years of age	Fracture; tumor	Operation; bed	Death; heat	Fibrous marrow; osteoid; malacia

32. Albertin: Province méd., Lyon **4**: 541. 1890.
33. Bramann: Verhandl. d. deutsch. Gesellsch. f. Chir. **1**: 31-36, 1887.
34. Koehl-Hanau: Cor.-Bl. f. schweizer Aertze **22**: 1892.
35. Saxinger: Beitr. z. klin. Chir. **79**: 219-232, 1912.

TABLE 3.—Cases in Group 1 (B 2)

Case	Age	Sex	Cysts	Malacia	Hyperostosis	Duration	Symptoms	Treatment	Outcome	Pathologic Report
Fujii[36]	36	♂	Vertebrae (2); left femur; right humerus	Sternum; right tibia; right fibula; ribs	Skull; left femur	Long time	Rheumatic pains	.....	Death; cause unknown	Fibrosis; bone building and withdrawal; few giant cells; cysts
Gottstein[37]	11	♀	Whole system	.....	Skull; hands	Since 4 years of age	Fractures	Not stated	Not stated	No examination
Katholicky[38]	30	♀	General	General	Skull; collar-bone; jaws; leg bones	Since 23 years of age	Pain; weakness; anemia	.....	Death; asthma; edema of lungs	Osteoid; sparse bone building
Klestadt[39]	35	♂	Left tibia; left femur; parietal bone	General	Skull	Since 14 years of age	Pain; fracture; deformity	.....	.....	No examination
Von Recklinghausen (1891) Case 5	66	♀	Right tibia; right femur; right calcaneus; right first metatarsal; right ulna; skull	Femurs; sternum; ribs; pelvis; spine	Skull; femurs	.....	.....	.....	Death; pneumonia	Osteitis; fibrosa; cysts; few giant cells
Von Recklinghausen (1891) Case 6	40	♀	?	Pelvis; pipe bones; spine	Skull; pipe bones	.....	.....	.....	Death	Skeleton only
Virchow[40]	?	♂	Fourth and fifth vertebrae; left tibia; right humerus; cranium; jaw?	Femurs; ribs; pelvis; spine; tibia	Skull; femurs; right humerus	.....	.....	.....	Death	Fibrosis; cysts; nests of giant cells

36. Fujii: Ztschr. f. Chir. **114**: 25-74, 1912.
37. Gottstein: Demonstration, Schleswig Gesellschaft für vaterländische Kultur in Breslau, July, 1907.
38. Katholicky: Wien. klin. Wchnschr. **19**: 1428-1429, 1906.
39. Klestadt, W.: Beitr. z. klin. Chir. **75**: 681-706, 1911.
40. Virchow: Tageblatt der Neun und Fünfzigen Versammlung Deutscher Naturforscher und Aertze, Berlin, 1886.

Paget's disease in some instances. Two of von Recklinghausen's original cases fall into this class. Von Recklinghausen concluded that the changes in his cases were all old and secondary to the active disease long ceased and that the hyperostosis and hardness of the new bone were secondary protective changes. This certainly does not hold for all the cases in this group as the active processes of calcium withdrawal and bone deposit are going on simultaneously, apparently representing two forms of reaction taking place much the same as in normal bone growth.

Both Groups B 1 and B 2 present deformities that are typical of this condition and advanced osteomalacia. The head is bowed down and forward, the chin resting on the sternum in the severest cases; the thorax is compressed laterally and bulges forward in a pigeon's breast deformity; the vertebrae are crushed together under the body weight, biconcave, "fish-like" vertebrae resulting; and the normal spinal contours are accentuated causing kyphosis in the dorsal, and lordosis in the lumbar region. Varying degrees of scoliosis occur. The whole result of the spinal change is to allow the patient to "sink together" and to make the arms seem disproportionately long for the body. Add to this the outward and forward bowing of the femurs and the forward bowing of the tibias and the attitude is that which has been aptly termed "anthropoid-ape like." The pelvis shows the most remarkable changes, being compressed at the sides, bulging forward at the symphysis in the "duck-bill" appearance, and the sacrum protruding into the pelvic cavity, giving the pelvic inlet the so-called "heart-shaped deformity."

Group 2 (A) is not represented by many reported cases, and Barrie was able to find but four in the American literature. One of these has been classed under Group 1 (A) because of inadequate pathologic examination. The only evidence we have that there were giant cell tumors in this case (Harting [24]) is a report of Kanavel [41] which came out a year later and states that in both cysts operated on "a granulomatous type of tissue was found." Barrie's case is remarkable in that there were no cysts present but numerous solid tumors, which he considered hemorrhagic osteomyelitis and which Ewing called giant cell sarcoma of the epulis type. In Crile and Hill's [42] case there is no mention made of cysts in the original report; but Dr. I. S. Hirsch of New York saw the same patient ten years later and said that "the roentgen ray showed multiple multilocular cystic tumors which had the typical appearance of what we now recognize as giant cell tumor." Haussling and Martland's [43] patient had a cyst in the right humerus. The foreign reports which seem best to fit into this class are those of

41. Kanavel, A.: Surg. Gynec. & Obst. **20**:745, 1915.

42. Crile, G. W., and Hill, W. C.: Surg. Gynec. & Obst. **3**:57-61, 1906.

43. Haussling, F. R., and Martland, H. S.: Ann. Surg. **63**:454-464 (April) 1916.

TABLE 4.—Cases in Group 2 (A)

Case	Age	Sex	Cysts	Malacia	Tumors	Duration	Symptoms	Treatment	Outcome	Pathologic Report
Barrie..... Case 1920	50	♂	None.....	Not marked	Skull; ribs of right side; long bones of lower extremity	Since 42 years of age	Weakness; pain in the legs	Exploration in left tibia for examination	Good	Giant cell sarcoma
Crile and Hill..	22	♀	Not mentioned.....	Not marked	Right ulna; right os magnum; right metacarpals and general	Since 21 years of age	Pain; swelling	Exploratory operation	Good	Multiple giant cell sarcoma
von Haberer..	10	♂	Right parietal; right femur; left femur; pelvis; ribs, etc.	Femurs; right humerus; left tibia	Parietal; right femur; left femur; lower jaw	Since 5 years of age	Swelling; deformity; fracture	Excision of tumors for examination	Good	Osteoid; cysts; giant cell sarcoma; fibrous marrow
Haussling and Martland	25	♀	Right humerus.....	Not marked	Right orbit; right femur; right humerus; clavicles; fibula, etc.	Since 21 years of age	Weakness; pain; tumor	Curettage of tumors	Good	Giant cell sarcoma
Werndorff.....	9	♂	Right pelvis; right femur; right tibia; right fibula	Right femur; right tibia	Right femur; right tibia	From earliest childhood	Deformity right leg	Resection of tumor; right femur	Good	Giant cell sarcoma; cysts; fibrous marrow
Wrede.....	40	♀	Almost all the bones; cranium	?	Upper and lower jaws	Since 30 years of age	Swelling	Operation; removal of tumors	Not stated	Giant cell sarcoma

von Haberer,[44] Werndorff[45] and Wrede.[46] There is no definite age of onset, the age in the reports varying from 9 years to 50 years; but the tumors may run a course of several years without injuring the health. The distribution is quite general and it does not seem satisfactory to attempt to classify by regions as Elmslie[5] has attempted. For instance, tumors of the jaw may arise in young or old and may run a rapid or chronic course.

The symptoms most often given are swelling, deformity, pain and fracture. The tumors do not seem to affect the course one way or another; there is no tendency to malignant change or to metastasis; but local recurrence is common unless operative removal is thorough. Bloodgood[1] has demonstrated, however, that a local operation is all that is necessary, even in recurrent growths. The bone reacts well to operation and tends to fill in the defect with solid tissue. Large tumors can be excised and bone grafts substituted with satisfactory results. The prognosis is good in all cases in this class.

There is some factor present in divisions B 1 and B 2 which causes a widespread malacia and a very severe general reaction. The resemblance to the corresponding divisions of Group 1 is striking. One of von Recklinghausen's[8] original cases and both of his 1910 cases fall into division B 1, as well as Hirschberg's[7] case, which is often referred to as the first description of the disease. Apparently, the occurrence of giant cell tumors in osteomalacia is sufficient to classify the case as osteitis fibrosa and many of the sixteen cases which have been put in B 1 were originally described as osteomalacia with cysts and tumors. The disease originates later in life, as a rule, being noticed after 30 years of age in almost all of the reports. The symptoms are pain, fracture and deformity, and the course is downhill. The patients become weak, anemic, emaciated and bedridden. Death follows in practically every instance after a period of suffering. On section the tumors may be few or numerous—quite a number of cases have but a single small tumor, whereas in others the skeleton is peppered with growths. The tumors seem to bear no definite relation to the severity of the disease.

Division B 2 differs from B 1 only in the occurrence of hyperostoses and thickening of the skull, which make it necessary to differentiate this condition from Paget's osteitis deformans. There are but four of these cases. Perhaps a better classification would place in one group all cases with marked malacia, irrespective of the presence or absence of tumor growth, for Groups 1 (B) and 2 (B) are similar;

44. Von Haberer, H.: Ztschr. f. Chir. **31**:1323, 1904.

45. Werndorff, R.: Ztschr. f. orthop. Chir. **32**:122-133, 1908.

46. Wrede: Verhandl. d. deutsch. f. Chir. **51**:73-74, 1912; Zentralbl. f. Chir. **35**:1400, 1908.

TABLE 5.—Cases in Group 2 (B 1)

Case	Age	Sex	Cysts	Malacia	Tumors	Duration	Symptoms	Treatment	Result	Pathologic Report
Butlin[47].....	50	♂	Left femur; right femur; right humerus	Femurs; calvarium; humerus; other bones	Jaw (2); sixth rib right	Since 43 years of age	Swelling; fractures	.....	Death; cause ?	Giant cell sarcoma; cysts; fibrous marrow
Davidsohn[48]...	58	♀	Both femurs.....	General	Tibia; patella; femurs	Since 56 years of age	Pain; fracture; edema	Medical	Death	Giant cell sarcoma; osteoid; fibrous marrow
Feldmann[49]....	28	♂	No roentgen rays....	General	Right lower jaw; left humerus; femurs ?	Since 17 years of age	Deformity; fracture; pain; swellings	Osteot.; medical	In poor condition when reported	No examination
Froriep.....	?	♀	Entire bone system; jaw	General	Pelvis; skull	Many years	Pain; fracture	.....	Death; cause ?	Fibrous marrow; giant cell sarcoma
Gaugele[50].....	36	♀	Sternum; ribs; vertebrae; humeri; right femur	General	Tibia; humerus; ulna	Since 28 years of age	Fractures; swellings; deformity; anemia; emaciation	Medical	Death; uremia	Fibrous marrow; giant cell sarcoma
Grasbey[51].....	54	♂	One radius; one ulna; one metacarpal	Entire skeleton	Fifth metacarpal	Since 50 years of age	Weakness; fracture	.....	Not stated	No examination
Hart[52].....	74	♀	General.....	General	General	Since 69 years of age	Bedridden; fracture; deformity	.....	Death; bronchitis and pneumonia	Giant cell sarcoma; cysts; fibroid marrow; osteoid
Hirschberg.....	35	♀	Left humerus; left femur; left tibia	General	Left tibia; left humerus; left femur	Since 31 years of age	Swelling; pain; emaciation	.....	Death; marasmus	Giant cell sarcoma; fibrous marrow; cysts; malacia
Lissauer[53].....	36	♂	Numerous.....	?	Right forefinger; Middle phalange	Since 8 years of age	Pain; swelling; fracture	.....	Death	Fibrous marrow; giant cell sarcoma; bone atrophy
Meyer[54]..... Case 1	43	♀	Left femur; left tibia; left calcaneus; lumbar vertebrae	Vertebrae especially	Right femur	Indefinite, 10-14 years	Pain; fracture	Operation	Death; cause ?	Giant cell sarcoma; cysts; fibrous marrow
Meyer..... Case 2	36	♂	Right femur; pelvic bones; skull	General	Multiple	Several years	Pain; fracture	Splint	Death; pneumonia	?
Von Recklinghausen (1891) Case 7	40	♂	Ribs, also in the tumors	General	Left ilium; upper and lower jaws; radius; tibia; ribs; fibula; femur	No data	Pain; fracture; deformity	.....	Death; marasmus	Giant cell sarcoma; cysts; fibrous marrow
Von Recklinghausen (1910) Case 1	33	♀	Left femur; right fibula; right tibia; cranium; metatarsals; metacarpals; phalanges	General	Lower end; left femur	Since 31 years of age	Fracture	Bed	Death	Cysts; fibrous marrow; one giant cell tumor
Von Recklinghausen (1910) Case 2	50	♀	General.....	General	Right pubis; horizontal ramus	Since 48 years of age	Unsteadiness; emaciation; pain; pallor	Bed	Death	Giant cell sarcoma; cysts; fibrous marrow; malacia
Rehn[55].....	23	♀	Pelvic bone; right	General	Right ulna; right numerous in both femurs; ribs	Since 14 years of age	Anemia; pain; swellings	Excision of tumors	Death; heart failure	Giant cell sarcoma; osteoid; fibrous marrow
Schönenberger[56]	33	♀	Left tibia..... fibula	General	Pelvis; right humerus; both tibias; pelvis; left pelvis; both femurs	?	Pain in back and legs	Medical	Death; bronchitis	Giant cell sarcoma; fibrous marrow

47. Butlin, H. T.: Tr. Path. Soc., London. **31**: 277-279, 1880.
48. Davidsohn, C.: Charité-Ann. **28**: 741-753, 1904.
49. Feldmann, G.: München. med. Wchnschr. **48**: 1840-1842, 1901.
50. Gaugele, K: Arch. f. klin. Chir. **83**: 953-975, 1907.
51. Grasbey: Atlas Chirurgisch Pathologischer Röntgenbilder; Lehmann's Medizinscher Atlas, 1908, vol. 6.
52. Hart, C.: Beitr. z. path. Anat. **36**: 353-374, 1904.
53. Lissauer: Monatschr. f. Unfallheilk. **12**: 51-56, 1905.
54. Meyer, O.: Frankfurt. Ztschr. f. Path. **20**: 115-159, 1917.
55. Rehn, L.: Verhandl. d. deutsch. Gesellsch. f. Chir. **33**: 424-431, 1904.
56. Schönenberger, W.: Arch. f. path. Anat. **165**: 189-226, 1901.

TABLE 6.—Cases in Group 2 (B 2)

Case	Age	Sex	Cysts	Malacia	Tumors	Hyperostosis	Duration	Symptoms	Treatment	Result	Pathologic Report
Hartmann[57]...	28	♀	Left iliac; right femur	Left femur; right femur	Left iliac	Skull	Since 15 years of age	Pain; deformity; swelling	Operation for tumor; operation for correction; opration for drainage	Death; operative collapse	Cysts; giant cell sarcoma; fibrous marrow
Kolisko[58].....	30	♂	Numerous.....	General	Numerous	Skull	.....	.....	.....	.....	Giant cell sarcoma; cysts
Lötsch.....	57	♀	Skull; ribs; hands; iliac bones; vertebrae; humeri; clavicle; wrists; right ulna; right radius; left tibia	General	Left tibia; right tibia	Skull	Since 47-50 years of age	Pain; emaciation; swellings; fracture	Exploratory operation, tibia	In fair condition at report	Giant cell sarcoma; cysts; fibrous marrow
Monckeberg[59]..	55	♀	Right humerus; right clavicle; right pelvic bone; right femur; jaw	General	Jaw; ninth rib	Skull	Since 39 years of age	Fractures; swelling of jaw	Extirpation of jaw tumor three times	Death	Giant cell sarcoma; cysts; osteoid; fibrous marrow

57. Hartmann, K.: Beitr. z. klin. Chir. **73**: 627-650, 1911.
58. Kolisko, A., Discussed by Katholicky: Wien. klin. Wchnschr. **19**: 1428, 1906.
59. Monckeberg: Verhandl. d. deutsch. path Gesellsch. **7**: 232-237, 1904.

and in a like way all cases with local softening only, because Groups 1 (A) and 2 (A) are also much alike. But in working through the numerous and confusing reports, the different factors were separated and cases assorted as nearly as possible by the presence or absence of these conditions.

PATHOLOGY

In his earliest description von Recklinghausen [8] regarded the disease as an inflammatory process, a chronic productive inflammation whereby fibrous tissue was substituted for bone structure, resembling in this way fibrous myocarditis or liver cirrhosis. In his later work he changed his belief and thought that he was dealing with a metaplasia of existing tissue and a calcium withdrawal. Whichever view is correct the pathologic picture is fairly constant. It is characterized by the building of a fibrous marrow which extends through the spongiosa strands and works its way into the cortical bone. This young fibrous marrow consists of finely fibrillar thready connective tissue with few nuclei, and is usually not vascular. In places it becomes infiltrated with round cells and appears as an obvious granulation tissue. The process of resorption goes on hand in hand with the new formation of tissue, differing from the normal in the persistence of the osteoclast giant cells, which gather together in small clumps. There is also some barrier to the deposition of calcium salts so that the bone formation remains in the osteoid tissue stage instead of going on to completion. The result of this resorption is that the bone is left weakened and softer than normal so that a true malacia occurs. A further step is the formation of cystic spaces in the poorly vascularized connective tissue. This is explained by von Recklinghausen [8] and Fujii [36] as simple atrophy and rarefaction through softening. The cysts always lie in the middle of the fibrous marrow at first and their walls are formed of thick fibrillae of this tissue, having a concentric arrangement and bound together by short strands. True epithelial or endothelial linings are lacking; but in spite of this the cavity walls are fairly smooth. The contents are usually fluid—thin or gelatinous, water clear, yellow or reddish according to the amount of blood extravasation. The changes noted occur in the beginning in circumscribed patches in individual bones. The whole bone becomes involved later by broadening out and confluence of the pathologically changed places. The epiphysis and periosteum, as a rule, remain unchanged. The metaphysis in young bone and the diaphysis in formed bone seem to be the places of predilection.

The formation of the giant cell tumors may or may not be extensive. In all cases, giant cells are present, but in one group in not sufficient numbers to form the masses of brown red tissue which has received so many names and caused so much controversy as to its nature.

There have been several quite divergent views as to the origin of these cells. Adami [60] believes that they are myeloplaxes and that they differ from foreign body giant cells in the even distribution of their nuclei throughout the cell body and in the absence of central degeneration of the cell, and that they differ from parenchymatous (true tumor) giant cells in that their nuclei are well formed, of uniform size, and lack mitotic figures. Mallory,[61] on the other hand, considers them to be foreign body giant cells due to fusion of endothelial leukocytes and attracted into the tumor by the presence of lime salts which they dissolve and remove. Both observers agree that they are similar to the osteoclasts normally present in Howship's lacunae. Barrie [62] has reproduced the medullary giant cell sarcoma experimentally by embedding a piece of sterile gauze in the bone marrow, and he agrees with Mallory as to the origin of these cells. He believes that they will be found wherever a suitable irritative agent is present and he regards them as evidence of a chronic nonsuppurating form of osteomyelitis. Haussling and Martland [43] are inclined to support Barrie's contention. Lubarsch [63] attempts to differentiate the giant cells in epulis, giant cell sarcoma of the long bones and giant cell building in osteitis fibrosa. He argues that in the first two conditions abundant pigment is present but never inside the giant cells; that in epulis the giant cells are uniformly packed together, and that in giant cell sarcoma of the femur and tibia one finds considerable polymorphism of the cells—hyperchromatic and irregular nuclei—mitoses, etc., are never wanting. In osteitis fibrosa, on the contrary, the giant cells are more or less full of pigment; they are irregularly distributed, clumped in one place and lacking in other places; mitoses are always wanting, also polymorphism, and there is seen a distinct transition of fibrous tissue to giant cell formation. Von Recklinghausen [8] disagrees entirely with this view and considers both epulis and giant cell sarcoma of the long bones to be the products of osteitis fibrosa.

There is abundant pathologic and clinical evidence at hand now, however, firmly to establish the benign nature of these giant cell growths. They grow locally only, do not metastasize, recur only on incomplete removal, and may be removed by local operation several times if necessary. The growth is expansive, leading to absorption of the surrounding bone and only very seldom breaking through the periosteum. Hemorrhage and tissue infarctions are common findings

60. Adami, J. G.: The Principles of Pathology, Ed. 2, Philadelphia, Lea & Febiger, 1910, vol. I.

61. Mallory, F. B.: Principles of Pathologic Histology, Philadelphia, W. B. Saunders Company, 1914.

62. Barrie, G.: Ann. Surg. **65**:151-158 (Feb.) 1917.

63. Lubarsch, cited by Gaugele: Reference 49, pp. 968-971.

in and around the giant cell collections and there is probably some relationship between the two. Barrie [62] believes that hemorrhage is an essential part of the production of the giant cell growths. The extravasated blood may well act as an irritant and attract these cells to its neighborhood, where they certainly appear to function as scavengers loading their cytoplasm with blood pigment. Blood pigment occurs also free in clumps in the tissues and is a sure evidence of old hemorrhage.

Where large collections of these cells have a poor central blood supply, softening occurs and cyst formation takes place. Thus in the second large group—fibrosis with tumors, two varieties of cyst may be found. Mönckeberg [59] has called attention to these:

1. Fibroma cyst—smooth softening with slight growing tendency, very little or no pigment, and marked proliferation in the surrounding bone.

2. Giant cell sarcoma cysts, arising through softening and extravasation of blood, rich in pigment, which showed great growth tendency, marked absorption of surrounding bone.

In the very extensive involvement of the skeleton the calcium withdrawal leads to marked changes. The bone loses its hardness, is liable to fracture and becomes bowed and deformed in many places. The softness is so marked that it is often possible to cut the bone with a knife at necropsy. The cortex and marrow melt into each other and cannot be differentiated. The characteristic deformities have been discussed under classification.

The pathologic fractures which are so common heal well and within normal time limits in spite of the changes in the bone. This is explained by the integrity of the periosteum which seems to be remarkably spared in this disease. Osteotomies heal well and Hartmann [57] has noted oftentimes an exuberant callous formation with long persistence.

The pathology of the internal organs shows practically nothing of moment. There is a decided contrast between the extensive pathologic condition of the bone and the relatively normal general findings.

Fujii [36] asserts that he is able to differentiate pathologically between osteitis fibrosa and osteomalacia, and offers the following criteria:

Osteomalacia.—This is marked by typical broad smooth osteoid seams without giant cells; bone corpuscles in general sparse and distributed irregularly, in the peripheral part of the bone framework, oftentimes wanting; bone framework, short, plump and scanty; bone marrow shows no connective tissue change.

Osteitis Fibrosa.—This is identified by small osteoid margins with formation of numerous lacunae which are filled with more or less numerous osteoblasts; bone corpuscles numerous and distributed regu-

larly, reaching to the free edges of the bony framework and communicating with one another by numerous long bony canals; bone marrow characterized by connective tissue change.

Axhausen [64] takes exception to this view and it does not coincide with Pommer's [65] ideas of the pathology.

ETIOLOGY

The etiology of the condition is obscure at present, and we have no definite factor that can be held responsible. The disease is certainly not due to any of the ordinary bacteria, as repeated attempts to grow microscopic organisms have been unsuccessful. The possibility that a filtrable virus may be the causative agent has as yet nothing to substantiate it.

The endocrine glands may have some bearing on the bone metabolism; but no constant findings have been reported. Hamann [23] cites a case which he studied, and in which he claims a remarkable cure was accomplished from the administration of hypophysis tablets. He draws the very sweeping conclusion from this case that osteitis cystoplastica, leontiasis ossea, and Paget's disease are due to hypofunction of the hypophysis. Nevertheless, the hypophysis has been reported without change in many of the necropsies of other observers. Meyer [54] found a tumor of parathyroid origin in a case of his and cites other similar findings of Schmorl, Erdheim, Askanazy, Strada, and Bauer in other closely related forms of bone disease. He concludes, however, that the finding is accidental and not a causative one. The other endocrines, especially the ovaries, have had their share of attention, but nothing final has been decided. There can be no question that there is some fundamental change in the calcium metabolism of these cases. It would be interesting to know whether the calcium salts were retained in high concentration in the blood and excreted more rapidly than in the normal, analogous to the sugar changes in diabetes mellitus.

ROENTGEN-RAY APPEARANCES

The roentgenogram in generalized osteitis fibrosa is typical. There is not the same necessity of differentiating these cases from the rarefactions due to acute infection—tuberculosis, syphilis, etc.—that exists in the single cyst cases; and even the malignant tumors of bone are rarely of such widespread occurrence. The only real conditions that might be confused with this form of the disease are osteomalacia and Paget's disease. In the first place, the periosteum does not take part in the disease and is smooth and normal in outline, except at the

64. Axhausen, G.: Arch. f. klin. Chir. **102**:281-331, 1910-1911.

65. Pommer: Untersuchungen über Osteomalazie und Rachitis, Leipzig, 1885, p. 87.

fracture places where it often heaps up a well marked callus. The epiphyses and joint surfaces also tend to remain unaffected. The cortex and marrow cavities show marked changes; the latter shows widening and irregularity in outline, and in places a mottled appearance, with here and there clear spaces which do not seem to have any calcium content. The cortical bone is also irregular, mottled, and in places thinned to a few millimeters only or destroyed. It is impossible at times to tell where the cortex leaves off and the marrow cavity begins, the process becomes so confluent. The whole bone picture is also striking because of the washed-out calcium content which gives a general translucence, and a honey-combed picture where cystic changes have occurred. Occasionally, cystic cavities show fine septal bridges making compartments, which some of the French observers compare to the cut surface of a tomato. Taken as a whole, the translucence of the bone, the irregular, rarefied patches and long porous streaks, the enlargement of the marrow space, and the replacement of the cortical bone and its lack of definition from the marrow cavity constitute a picture not liable to be mistaken for any other condition. The bony deformities are marked, and the bones are angulated where fractures have occurred so that a smooth curve is not the usual finding. The bones show expansion and reinforcement on the concavity of the cortex, but the latter never of marked density.

The roentgen-ray diagnosis from osteomalacia is not possible in one group of cases; the other offers no difficulty. Osteomalacia is usually a condition of marked calcium withdrawal and presents a uniform thinned shadow scarcely more dense than the surrounding soft parts. The cortical bone is regularly atrophied; cystic spaces occur but rarely, and fractures remain with very little sign of healing. Deformities are angular and the bone looks crumpled and bent, as if putty-like.

Paget's disease of the bone is in decided contrast, with its rough, irregular periosteum, tremendously thickened subperiosteal cortical bone, often two or three times the normal, marrow space that is mottled and gives a cloudy, furred, smoky appearing shadow generally distributed over the whole bone even to the epiphyses and joint surfaces, smooth even curves to the deformed bones, well healed fractures when they occur, and is especially distinctive with its markedly thickened calvarium which looks as if it were filled with cotton wool or rolling smoke. Cystic spaces do occur but are rarely more than 1 or 2 cm. in diameter. The outstanding feature is proliferation in this condition; the predominant thing in osteomalacia is calcium withdrawal, the so-called "bone-atrophy"; and the latter condition with bone replacement by cystic cavities, and tumors characterizes osteitis fibrosa cystica.

DIAGNOSIS

In one group of cases, diagnosis is made from the onset in early life, the chronic course, the absence of symptoms, the occurrence of fracture from a trifling injury, the good healing, and the characteristic roentgenogram. The slowly developing deformity of one or more bones is also a feature.

In the second group, the onset occurs later in life and practically all the cases have been described as osteomalacia, from which it is distinguished by microscopic examination of tissue. This is a very much more severe type of involvement and the general condition is bad; the deformities are marked and crippling, and the suffering is intense.

DIFFERENTIAL DIAGNOSIS

There are two conditions that may simulate generalized osteitis fibrosa cystica, and these are differentiated without much trouble.

The first of these diseases is osteomalacia, which exists in two general forms, the puerperal and the nonpuerperal. The puerperal form of the affliction comes on usually after twenty years in women who are pregnant or who are in the puerperium, and manifests itself first in the pelvis and bones in relation to it. There is a softening of these skeletal parts, often accompanied by pain and tenderness over the affected regions. Deformity of a characteristic type follows quite rapidly, the gait becomes waddling and uncertain, and the patients cannot get about with facility. The kyphoscoliosis, sinking in of the sternum, decrease in height, heart-shaped pelvis, bowed femurs with sharply contoured angulations, and the evidence of general metabolic disturbance—anemia, and emaciation—are not seen in any other condition, except one of the forms of generalized osteitis fibrosa, from which no distinction can be made in life. The nonpuerperal form may occur at any time of life, and is in no way different from the description given above. It may occur as juvenile or senile osteomalacia, though both these groups have been questioned, especially by von Recklinhausen. The roentgen-ray appearances serve in the differential diagnosis.

Paget's disease comes on later in life as a rule, though cases have been reported in the early twenties. It is more common in men; the course is a steady, slow progression, and does not go by fits and starts as in generalized osteitis fibrosa. Fracture is a relatively rare occurrence, in decided contrast to its frequency in osteitis fibrosa cystica. Cysts when they occur are very small, the skull is more frequently involved and the roentgenogram is entirely distinct.

PROGNOSIS

The groups of the disease not associated with general malacia, whether with or without giant cell tumors, have a very favorable outlook. The course is long and the progress slight. The fractures heal well, and deformed bones can be straightened by operation. This group of patients are not disabled by the disease unless malunion or nonunion results from fracture.

The other group in which general malacia plays a leading rôle has a much less promising outlook. The disease progresses with disabling deformities and pain, and, though it may extend over some years, it is in other cases quite rapid. The termination is with wasting anemia and bedridden invalidism.

TREATMENT

Nothing is known that will check the underlying metabolic process. The use of phosphorus and arsenic has not been successful in this class of cases. Calcium feeding does not seem to be of any use. Organotherapy can be tried; but reports are conflicting as to its value. Removal of the ovaries has led to no beneficial results. The treatment of symptoms is indicated whenever opportunity arises. Pain should be controlled if necessary by use of coal tar products; opiates should not be used on account of the chronicity of the condition. Fractures should be splinted as in ordinary cases unless a chance is offered of correcting the deformity by this means. Osteotomy should be resorted to freely and without anxiety as to the result when marked deformity demands correction. Malunion and nonunion of fractures have been successfully treated by freshening the ends and by the use of bone grafts (Meyerding [4]).

ACUTE HEMATOGENOUS OSTEOMYELITIS

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In view of the fact that an early diagnosis is rarely made in cases of acute osteomyelitis, and that the recognized textbook treatment of this condition in the early stage is open to question, it seems desirable that the subject should be reviewed and the experience of a large hospital clinic placed before the surgical public.

The condition which we call osteomyelitis is essentially an inflammation of all the structures of the bone, and really should be designated a periosteomyelitis. It seems incredible that an acute infection could be limited to the cancellous bone or to the periosteum, in view of the easy access and free communication between these by means of the haversian canals and para-epiphyseal line.

ANATOMIC CONSIDERATIONS

It is necessary in studying this problem to remember some of the anatomic features as they relate to bone growth and development. The circulation of an ordinary long bone, as described by Lexer, is derived from three sources:

The nutrient artery enters the shaft at about its middle and divides, sending branches to either extremity, which, after numerous divisions, end in fine capillaries near the juxta-epiphyseal line or metaphysis.

The epiphysis gets its blood supply from the cortical branches, which find their way in from the cortex along the epiphyseal line and are distributed to the whole of the epiphysis.

The cortex of the entire shaft receives its nutrition from the periosteal vessels.

The epiphysis in each long bone is, in most cases, not united by bone until early in adult life. The growth takes place on the diaphyseal side of the growing line, as can be demonstrated by an attempt to separate the epiphysis.

By forcibly tearing off the epiphysis from the shaft in the growing bone, it is seen that the separation takes place at the diaphyseal side of the epiphyseal line, and leaves an irregular series of indentations. In the child, the periosteum continued down from the shaft dips into the epiphyseal line and becomes densely adherent at this point. This condition prevents, in most cases, direct extension of infection to the joint.

ETIOLOGY

Osteomyelitis is practically always a blood-borne infection from a primary focus situated elsewhere in the body. This primary focus may

be the tonsils or mouth cavity, but much more frequently some local infection of the skin, as boils or infected wounds and cellulitis. The commonest type of organism is *Staphylococcus aureus* and some strains of the streptococci.

The blood stream infection is most frequently transient and cultures may be obtained but rarely. When the blood culture is positive and repeated, a general septicemia results, and recovery is uncommon.

The element of trauma must play a part in determining the seat of invasion. When one remembers that it is possible to wrench an epiphysis in a growing child sufficiently to produce pain or even hemorrhage

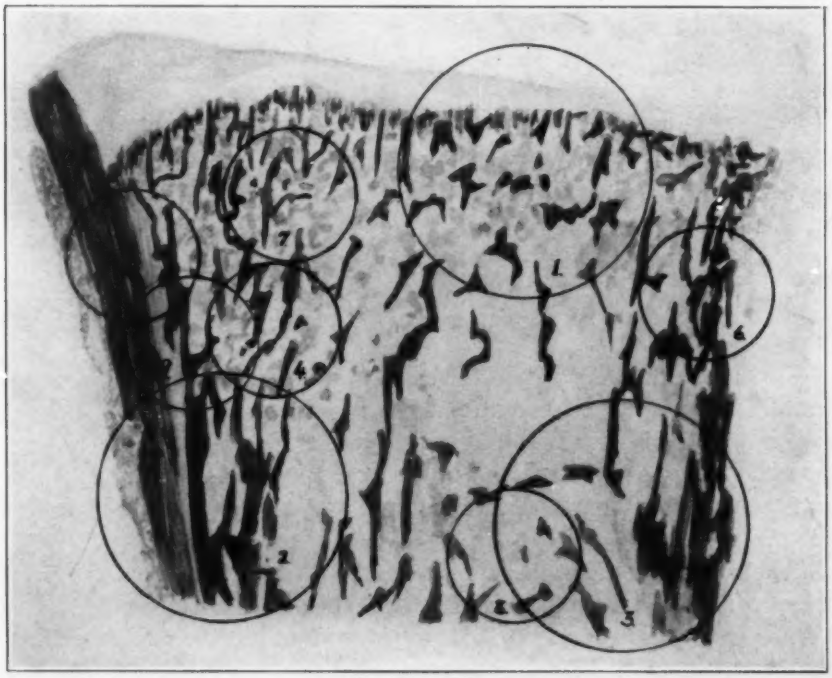

Fig. 1. — Drawing from photomicrograph, showing usual type of bone inflammation.

into the line of growth, it is easily seen that the resistance will be lowered at this point, and a good culture medium provided as well. Hence it is probable that an injury may be the determining factor in localizing the site of invasion.

In our experience, the bones primarily affected are, in order of frequency, the upper end of the tibia, the lower end of the femur, the lower end of the tibia and fibula, the lower end of the humerus, the upper end of the femur, the lower end of the radius, and then the ulna, the bones of the tarsus, the crest of the ilium and the scapula, in that order.

These findings strengthen the view that trauma is a distinct factor in the disease, as it is noted that they show a greater percentage of invasion at the points most subject to injury. The lower extremity shows a higher percentage than the upper, and the neighborhood of the knee the greatest of the lower extremity.

AGE

Acute osteomyelitis is essentially a disease of childhood. It occurs at this period because the actively growing bone is less resistant to infection than adult tissue, and because trauma at the epiphysis is possible only at this age.

It is extremely rare to find osteomyelitis in the adult, aside from that due to direct injury to bone and primary infection, such as is found in compound fractures and bullet wounds. The commonest age is from 2 to 10 years.

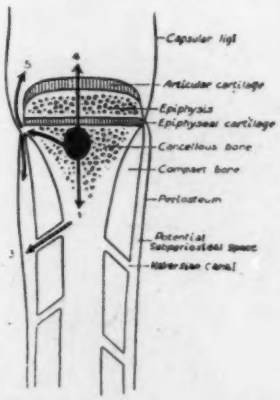

Fig. 2.—Schematic representation of a long bone, showing direction of possible spread of infection from the metaphysis (para-epiphyseal or juxta-epiphyseal region). (From Choyce, System of Surgery.)

SEX

Boys are slightly more frequently affected than girls, possibly owing to increased opportunity of injury.

PATHOLOGY

It is obvious that a true conception of the pathology of this condition must be built up, as upon this the treatment to be adopted necessarily depends. Our experience does not entirely correspond to the average textbook teaching, hence it is presented in more detail than might seem essential.

The offending organisms are carried through the blood stream to reach the finer capillaries in the juxta-epiphyseal region of a long bone. If the general resistance of the individual is lowered by ill health,

and the local resistance is lowered by trauma, the infective process is started, and a small inflammatory area in the cancellous bone near the epiphyseal line results. This area shows the usual type of bone inflammation, as is illustrated by Figure 1.

The commonly accepted view is that from this focus the infection spreads with greatest rapidity through the cancellous bone to the medullary canal, and in a few brief hours may involve the whole interior of the shaft. Then it is said to spread outward through the haversian canals to the periosteum, and to undermine this structure.

Fig. 3. — Necropsy specimen, showing early focus of infection in the tibia.

That it may spread downward through the epiphysis, and at times under the capsule of the joint, where it invades the joint, is also generally accepted.

Figure 2, taken from Choyce's System of Surgery, illustrates the commonly accepted view of the spread of infection. It is noted in the diagram that the chief spread is through the cancellous tissue into the medullary canal. In the text it is stated that "infection tends to spread through the cancellous tissue into the medulla, and *perhaps* also down under the periosteum."

In our experience, the focus of infection located in the metaphysis spreads fairly rapidly along the line of the epiphysis to reach the periosteum. Frank pus is here formed, and the infection spreads rapidly under the periosteum, stripping this structure from the bone surface. It spreads less rapidly through the cancellous tissue to the medullary canal, and the medullary canal is more frequently invaded through the haversian canals, secondarily to the periosteal infection.

This seems to be susceptible of demonstration by necropsy specimens which have been recovered from patients dying early of general septicemia, from roentgen-ray findings of the cases seen at all stages, and from animal experiments.

Fig. 4.—Necropsy specimen, showing early infection with inflammatory changes, marked at the periosteum and epiphyseal line.

The tibia shown in Figure 3 was recovered at necropsy from a child, aged 2 years, who died of septicemia forty-eight hours after the onset of symptoms. It is readily noted in the specimen that the focus of infection is just above the lower epiphyseal line, and of comparatively small extent. The gross appearance shows the inflammatory area localized in this region. The microscopic section shows large colonies of cocci in the same area, with marked infiltration of the cancellous tissue by large mononuclear leukocytes, and already some degeneration showing areas of necrosis. Higher up the shaft and in the medullary canal, there is no gross appearance of inflammation, and the sections show no organisms or evidence of inflammatory change.

The periosteum shows intensive infiltration in the neighborhood of this focus, and, as shown in the illustration, is stripped completely

from one epiphysis to the other and for nearly half the circumference of the shaft. There is marked inflammatory change throughout the whole area of the stripped periosteum.

The culture from this pus showed a hemolytic streptococcus, and a culture from the blood of the patient before and after death showed the same organism.

The specimen shown in Figure 4 was obtained at necropsy from an older child who died, on the third day after the onset of symptoms, of

Fig. 5.—Photomicrograph of section from specimen shown in Figure 4.

acute septicemia. This shows even more characteristically the points brought out in Figure 3, but the periosteal stripping is not so extensive. The gross appearance shows an irregular area of gray necrosis, surrounded by dense infiltration of the cancellous tissue and an extension to the periosteum, with periosteal stripping for about 3 inches (7.6 cm.) up the shaft, and about two-thirds around the circumference of the shaft.

Figure 1, and the microscopic sections, present the microscopic appearance of this specimen and show a marked inflammatory process in the cancellous portion of the bone, concentrated and apparently most acute at the epiphyseal line. There are large colonies of cocci, with marked infiltration of the cancellous bone with large mononuclear leukocytes. Many of these have degenerated, leaving masses of necrotic material. There are large numbers of giant cells or osteoclasts in this area, which have dissolved the bone salts and left little depressions.

Fig. 6.—Photomicrograph of section from specimen shown in Figure 4.

The inflammatory exudate extends outward, and involves the periosteum on each side, showing diffuse and focal areas of infiltration with these large mononuclear cells. In the periosteal area, there is a moderate endarteritis, and some of the lymphatics are filled with cocci. Small areas, as indicated in the illustration by rings, show varying concentration of inflammation, greatest at the epiphyseal line and along the periosteal margins, as shown in Figures 5, 6, 7, 8, 9, 10, 11 and 12.

Figure 13, taken at the highest point of the cancellous tissue, near the center and approximating the medullary canal, is shown free from inflammatory exudate.

ROENTGEN-RAY FINDINGS

There are several facts of importance in the study of the roentgenograms.

1. Roentgen-ray findings are always negative in the early stages. It is not until gross destruction of cancellous bone has taken place, or until new bone begins to develop as an involucrum, that the roentgenograms reveal any definite picture. This is too late to be of any diagnostic value, and it should be emphasized here that roentgen-ray findings should not be waited for in making a diagnosis.

Fig. 7.—Photomicrograph of section from specimen shown in Figure 4.

Figure 14, taken six days after the onset, shows only a slight change in density on the diaphyseal side of the epiphysis. The physician in charge of the patient had two roentgenograms made previous to this

one, and no bony change was reported. On admission, on the same day that the accompanying roentgenogram (Fig. 14) was made, incision demonstrated pus in fairly large quantity under the periosteum, firm attachment of the periosteum at the epiphyseal line, and the periosteum stripped nearly to the upper end of the shaft.

Figure 15, taken six months later, shows the amount of the destruction of the shaft.

2. Roentgenograms of cases of osteomyelitis which have been opened through the periosteum even moderately early, all show a fairly

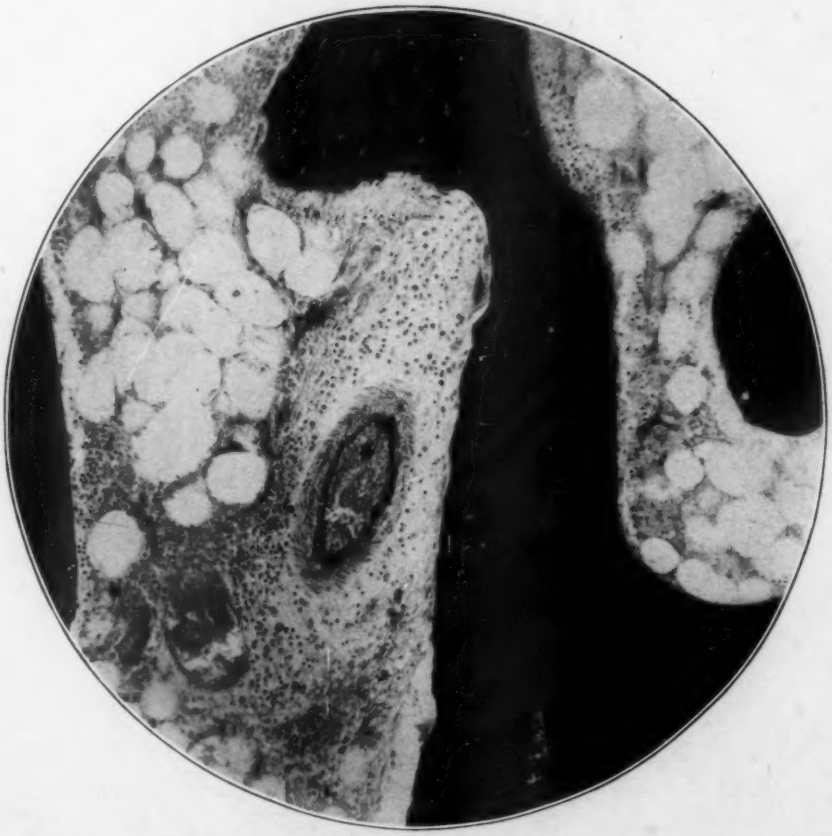

Fig. 8.—Photomicrograph of section from specimen shown in Figure 4.

similar picture. The bone changes always extend farther up the shaft on the periosteal side, than in the medullary area, and for the most part the periosteum is stripped higher on one side than on the other, and consequently, the destroyed part is wedge-shaped, with the base at the epiphysis and the apex on one side of the shaft.

Figure 16 shows a much greater advance of the disease along the cortical area than in the medullary area. This roentgenogram was

taken one month after onset, and the physician had evacuated pus from under the periosteum on the seventh day. The relief of tension under the periosteum had at once limited the extension of the disease both in the medullary area and under the periosteum.

Fig. 9.—Photomicrograph of section from specimen shown in Figure 4.

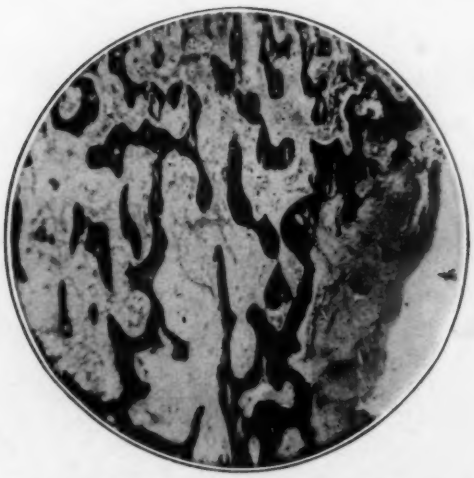

Fig. 10.—Photomicrograph of section from specimen shown in Figure 4.

3. Roentgenograms of still later cases, when the tension of pus under the periosteum has not been relieved, show a characteristic "spotty" infection, as if the organisms had been poured through the cortex at various places. This is well shown in Figure 15, where the periosteum was not incised until nearly entirely stripped.

Figure 17 was taken six months after the onset, during which time no treatment had been instituted, but the abscess had been allowed to burst. This also shows the spotty character of the infected bone, as well as areas of shaft and medulla which appear quite normal.

Fig. 11.—Photomicrograph of section from specimen shown in Figure 4.

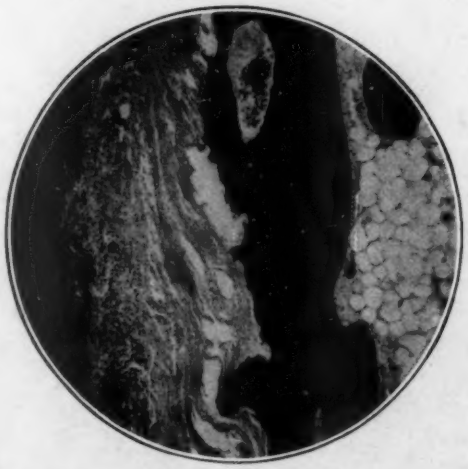

Fig. 12.—Photomicrograph of section from specimen shown in Figure 4.

ANIMAL EXPERIMENTATION

At first in our experimental work, which has been carried on largely by Dr. R. I. Harris, we found great difficulty in producing osteomyelitis in the dog, even with staphylococci or streptococci of known virulence in man. Therefore, our earlier demonstrations were

chemically produced with croton oil, sealed with agar and planted in the bone near the epiphysis, as employed by Bancroft and Clarke. These experiments succeeded in demonstrating the process of destruction and sequestration, but were not satisfactory as proof of the spread of infection. It was found that by tying off the appendix and its mesentery in the dog a general peritonitis is produced. The organisms from this infection if injected into a nutrient artery or into the traumatized metaphysis will produce an acute osteomyelitis in the growing dog. In every case the dog has died within forty-eight hours, but the osteomyelitis is characteristic. The periosteum is rapidly stripped, with findings similar to the sections shown.

No dogs lived long enough to allow the production of later changes and sequestration; but it is quite apparent that the early changes are

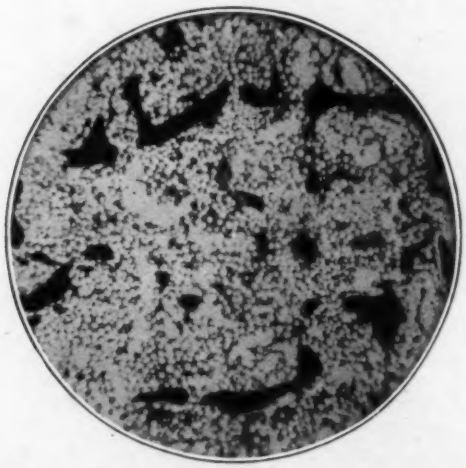

Fig. 13.—Photomicrograph of section of cancellous bone near medullary canal (Fig. 4).

in the nature of an inflammatory condition along the epiphyseal line, with rapid extension to the cortex, and frank pus under the periosteum.

From the foregoing presentation of early pathologic changes shown from human necropsy specimens, from the roentgen-ray findings of cases of longer standing, and some of late cases, and from the correspondence of the findings in the animal experiments, it seems reasonable to conclude, that, for the most part, infection starts in the metaphysis or diaphyseal side of the epiphyseal line; that it extends most easily along the epiphyseal line to the cortex and the periosteum; that it readily and early strips the periosteum, with increasing tension as more pus is formed; that with increased tension the infection probably spreads backward through the haversian canals at various levels, and invades the medulla from the cortex, giving this spotty character to the shaft infection.

One should feel that the firm attachment of the periosteum is a safeguard to direct extension to the joint by this route. It is also most unlikely that infection will travel through the epiphysis and articular cartilage direct to the joint.

Fig. 14.—Roentgenogram taken on the sixth day after onset, showing no bony change.

The neighboring joint is, no doubt, involved in a small number of cases; but I am beginning to believe that it is more often infected secondary to operation, than as a result of primary extension.

That a serous synovitis occurs from adjacent infection, and consequent hyperemia of the synovial membrane, is unquestioned; but these will usually subside without aspiration or incision.

The changes occurring in the later stages are so well known that they need no elaboration. The formation of a bony wall or involucrum on the under surface of the periosteum, the sinuses passing through

Fig. 15.—Roentgenogram of same case as that shown in Figure 14, six months later.

this bony covering, the gradual separation of the necrotic area or sequestrum by a layer of granulation tissue forming between the living and dead areas, are conditions which are well described in most textbooks.

SIGNS AND SYMPTOMS

Following a fall or moderate injury, there is complaint of pain, severe, of sudden onset, and located in the neighborhood of a joint. This may be preceded a few days by a sore throat or a discharging ear, or some other primary source of infection may be found. Accom-

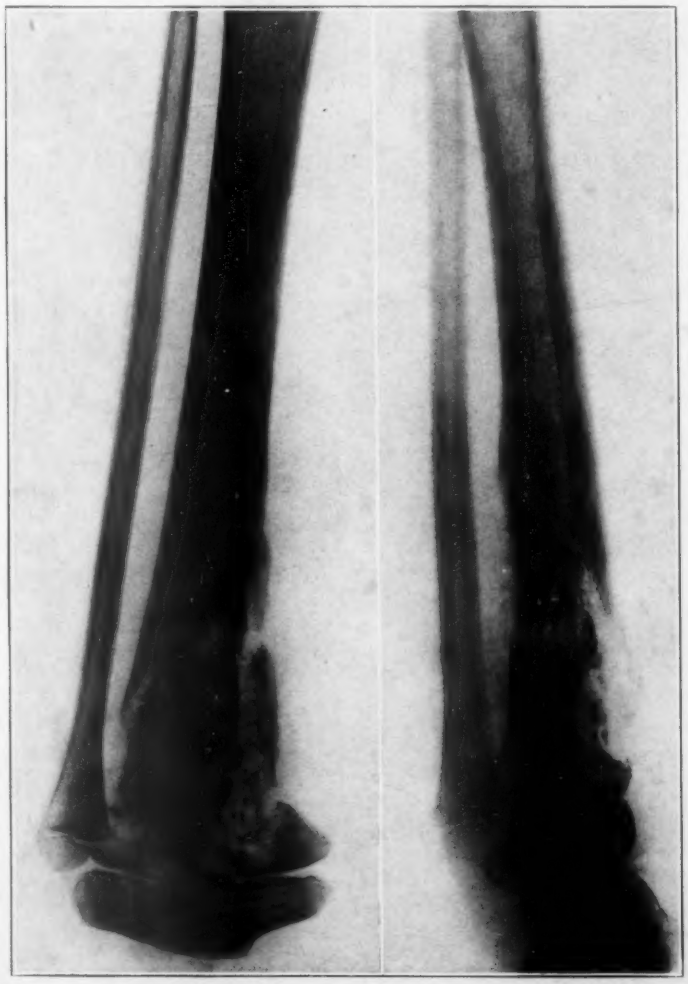

Fig. 16.—Usual appearance of untreated bone.

panying the pain, there will be tenderness over a limited area, and most extreme at that point. There will be signs of toxemia, headache, dry tongue, sometimes vomiting, with a pulse rate as high as 120 or 130, a temperature of 103 or 104 F., and a marked leukocytosis as high as 25,000 or 30,000. If left alone, later symptoms of redness, swelling,

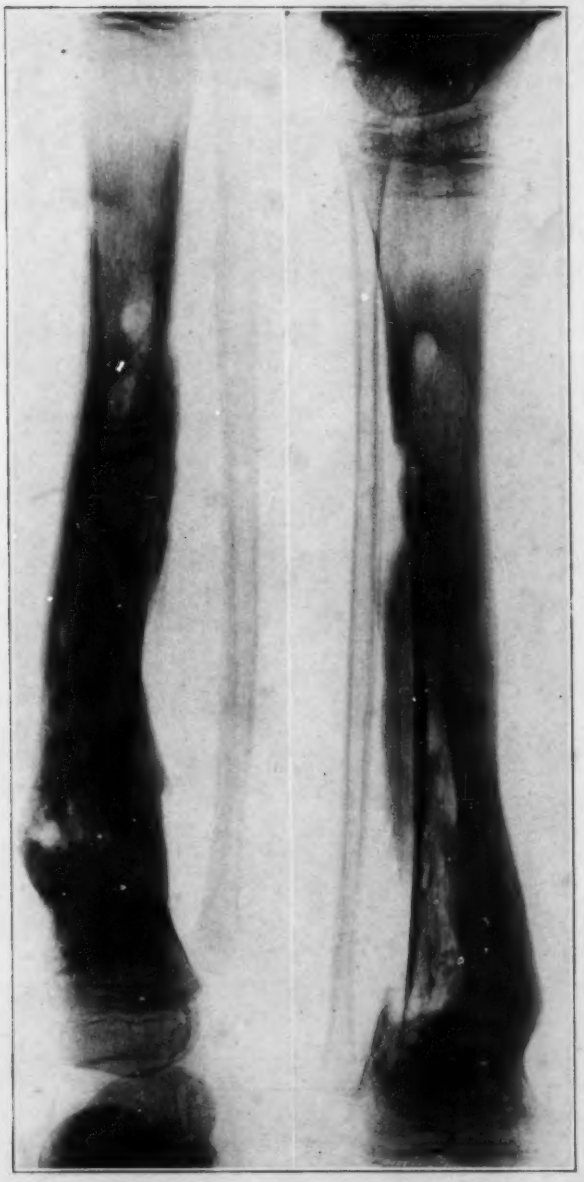

Fig. 17. — Roentgenogram taken at a late stage, showing "spotty" infection.

and marked edema develop. With these there is a corresponding increase in the toxic symptoms.

DIAGNOSIS

The diagnosis must be made on the signs present. Severe pain in the neighborhood of a joint, with a spot of extreme tenderness, in a growing child is extremely significant. If it is accompanied by high fever and rapid pulse, with high blood count, the diagnosis is moderately certain.

It is so essential that an early diagnosis be made, that one should be constantly on guard. The roentgen ray is of no assistance in early

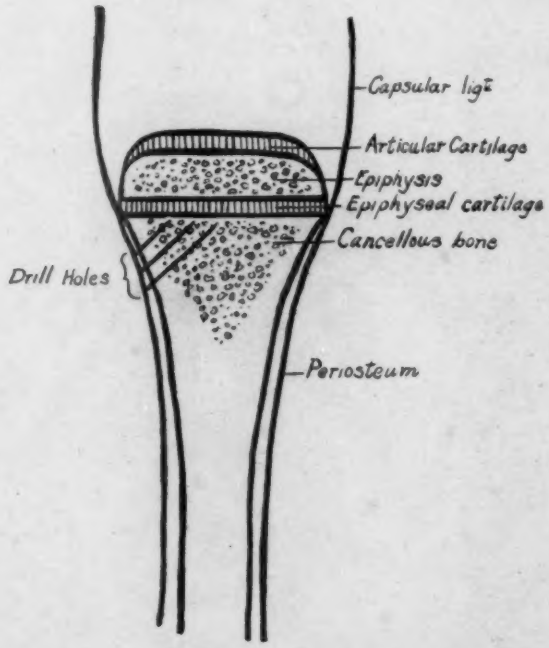

Fig. 18.—Series of drill holes from cortex to epiphyseal line.

diagnosis. Valuable time is consumed, which means more and more bone destruction. Salicylates should not be administered if time is lost thereby.

In rheumatism the onset is not usually so severe, nor the pain so excruciating. There is no sharp point of localized tenderness, and the pain is articular, not in the neighborhood of the joint. There is almost immediate swelling of the joint in rheumatism.

An infectious arthritis is sometimes confusing; but the joint manifestations are usually sufficient to differentiate this condition. There is muscle spasm, limited movement of the joint, and early swelling of

the synovial pouch. In osteomyelitis the joint is usually free of swelling, and movements are free if gently attempted. Do not wait for signs of swelling, redness and edema, as these are rather later signs. Of course, if these are present when the patient is first seen, they render the diagnosis still more certain.

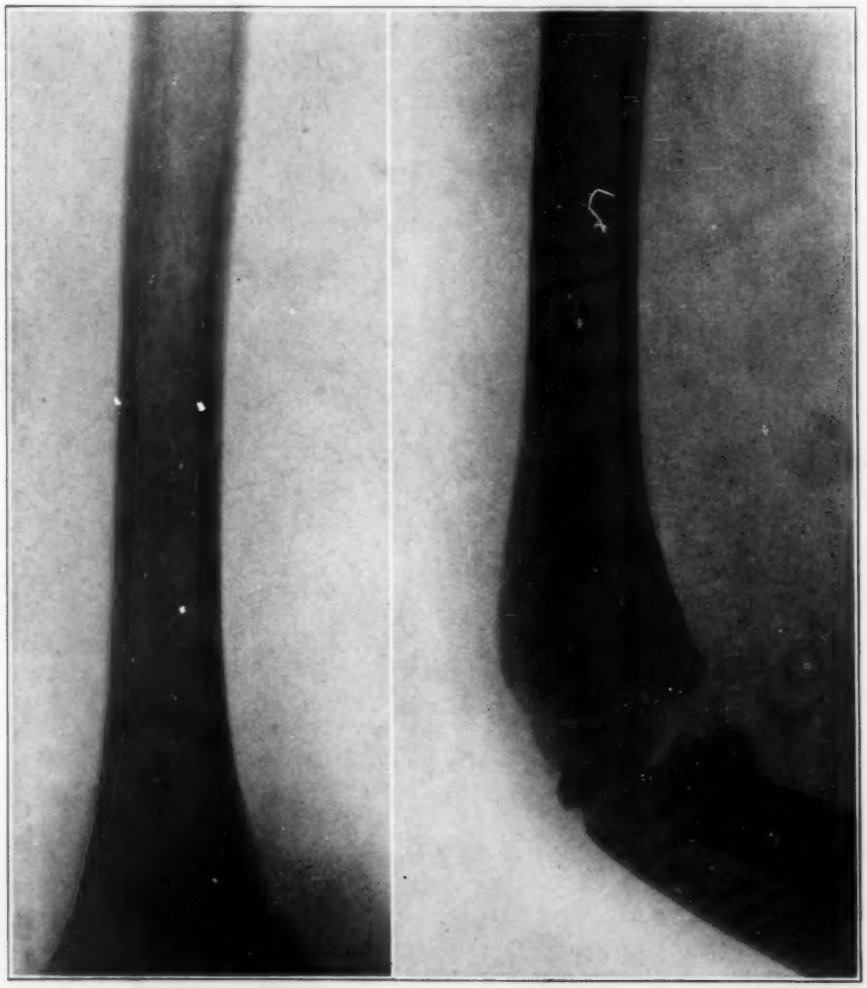

Fig. 19.—Arm of patient on admission.

TREATMENT

The diagnosis being made early, treatment should consist of incision over the area of greatest tenderness, through the skin, subcutaneous tissue and periosteum to the bone. Care should be exercised to keep the incision clearly on the diaphyseal side of the epiphysis to preserve

the periosteal attachment to the epiphyseal line. This safeguards to a large extent the possibility of extension to the joint.

If frank pus is encountered, our experience shows that this incision is sufficient, if a drain is kept in for a time. If no gross pus is encountered, the periosteum is stripped for a short distance on either side of the incision, to be sure that the incision is not in the wrong place.

If still no frank pus is seen, a series of possibly three drill holes is made from the cortex, obliquely downward toward the epiphyseal line. These are about one fourth of an inch (6.4 mm.) apart up the cortex, and extend at least into the center of the shaft at the epiphyseal line, as shown in the diagram (Fig. 18).

Cultures from the débris removed from these drill holes always show infective organisms, even though free pus is not obtained. These establish clear lines of least resistance, and within twenty-four hours pus is draining freely.

In no case have we opened the medullary canal, and in all cases the infected bone seems limited to the area present at the time of establishment of drainage.

The treatment, usually advocated, of trephining an opening into the medullary canal, 2½ inches (6.4 cm.) or more up the shaft, seems, in the light of our experience, to be pernicious.

If the periosteum is opened and holes drilled into the shaft at the metaphysis (Fig. 18), one can hope to relieve the symptoms and prevent necrosis sufficient to produce sequestration. Even if free pus has stripped the periosteum, if it is confined to a small area, regeneration of the necrotic area may take place without sequestration. The subjoined case illustrates this type.

A. B., a boy, aged 12 years (Fig. 19), had sore throat, headache and cervical adenitis, one week before onset of symptoms in the arm. Two days before admission he had pain, which increased in severity just above the left elbow. Slight swelling was noted the day before admission.

On admission he had pain just above the left elbow, some swelling and redness over the inner aspect of the humerus, with pitting on pressure and exquisite tenderness. Movement at the elbow was nearly complete in range, and only painful when the arm was extended to its extreme length. The temperature was 103 F.; the pulse 150; respirations 30; white blood cells 24,000; polymorphonuclear leukocytes 98 per cent.

A free incision over the inner side of the lower end of the humerus, above the epiphyseal line, opened a cavity containing ½ ounce (15 c.c.) of pus. Culture from this pus showed a hemolytic streptococcus. A blood culture taken at the same time was sterile.

The boy had a rapid convalescence, and was discharged from the hospital at the end of three weeks, with the wound healed. It has remained healed ever since, now one year.

Figure 20, a roentgenogram taken four months later, shows some periosteal thickening and no cancellous tissue change.

In the series of patients under treatment there are six that have been similarly treated; and the wounds have healed in three or four weeks without a sequestrum being formed. There are also three patients with positive blood cultures on repeated examination, who recovered with greater or less sequestration of necrotic bone.

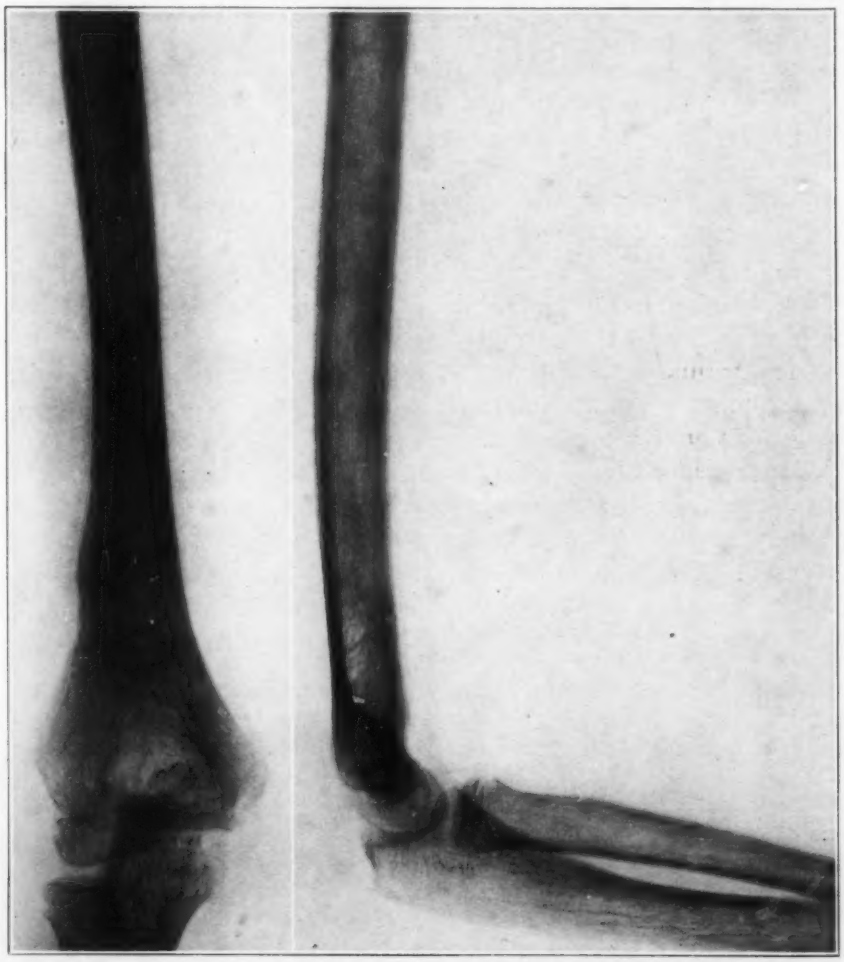

Fig. 20.—Arm of patient, four months later.

In the later stages the plan of treatment adopted is this: After efficient drainage has been established, operation is delayed until the sequestrum is separated. Then a channel sufficiently large to remove the sequestrum is chiseled through the involucrum; the cavity is gently

curetted until it is free of dirty granulations; the cavity is sponged with iodin, and packed tightly for forty-eight hours with iodoform gauze after which all packing and drains are removed. If the cavity left is too large to fill easily by granulation, the edges are made saucer-shaped, or flattened, to permit the soft tissues and periosteum to fall in and obliterate it.

It is rare to find in hematogenous osteomyelitis the large central cavities that one finds in osteomyelitis near the extremity of a long bone following a gunshot wound, which can best be obliterated by a transplanted muscle flap.

The practice of attempting to chisel away necrotic bone before it has delimited itself is to be condemned, as it is impossible to determine where the necrotic bone ends and where the living bone begins. Living bone is thus either taken away or necrotic bone left.

In the operation of making a depressed or saucer-shaped cavity the periosteum should not be widely separated from the living bone, as this is likely to interfere with the circulation of the bone tissue immediately underneath, which may also have its endosteal circulation cut off. This would, of course, make a new necrotic area and subsequent sequestrum.

The blind curetting of a bone cavity where there may or may not be a sequestrum, is not a procedure which is likely to produce any beneficial results. In our experience the sequestrotomy should be performed in a bloodless field, using a tourniquet wherever it can be safely used.

Ill-considered and incomplete operations in the latter stage are largely responsible for the fact that in so many of these bone cases discharging sinuses continue for years, and the patients are subjected to operations without number.

OPEN PNEUMOTHORAX IN ITS RELATION TO THE EXTIRPATION OF TUMORS OF THE BONY CHEST WALL*

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Perhaps no surgical condition of the chest is more germane to the discussion of pneumothorax than that of tumors of the bony chest wall. Such tumors are usually either malignant or potentially malignant, and often involve an extensive portion of the wall of the thorax. Complete extirpation with a wide margin necessitates an extensive resection, and furthermore, this operation, usually performed in one stage, results in a sudden collapse of the lung. In contrast to conditions following surgery for infectious diseases, there are no inflammatory adhesions of the pleura, and no thickening and fixation of the mediastinum. The posture of the patient, which is usually lateral or dorsal, is favorable to the collapse of the lung and to the transmission of atmospheric pressure to the other side. The operation is concerned with the chest wall, and not with the lung; retraction of a lobe of the lung outside the wound is neither necessary nor convenient during resection. There is consequently no steadying of the mediastinum. A study of operative pneumothorax incident to the resection of tumors under such conditions should be of importance, both with respect to the theoretical and to the practical considerations of the subject.

Resection of the entire chest wall with wide opening of the pleural cavity was practiced before the nature of pneumothorax or the dangers incident to it were adequately conceived. The first case of thoracotomy for tumor was recorded by Osias Aimar,[1] who, in 1778, removed an osteosarcoma involving the fifth, sixth, and seventh ribs; but he did not open the pleura. The first case of thoracotomy for tumor in which pneumothorax resulted was reported, in 1818, by Richerand,[2] who, with the assistance of Dupuytren, widely opened the pleural cavity by resecting a portion of the pleura with a carcinomatous growth involving the ribs. Richerand describes the onset of the pneumothorax, as follows:

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* From the Section on Surgery, Mayo Clinic.

* Read before the fourth annual meeting of the American Association for Thoracic Surgery, Boston, June, 1921.

1. Aimar, Osias: Quoted by Parham, F. W.: Thoracic Resection for Tumors Growing from the Bony Wall of the Chest, New Orleans, 1899.

2. Richerand, quoted by Parham: Footnote 1, second reference.

"At this moment the exterior air made an eruption into the chest, rushing in with violence and compressing the left lung which, with the heart, was borne toward the orifice. I sought, by placing thereto the left hand, to moderate the entrance of air and to prevent suffocation, which appeared imminent, while with the right hand I applied to the wound a large bolster spread with cerate. The entrance of air was suddenly stopped by this greasy cloth." The patient recovered from the operation, but died of recurrence one month later.

It was not until 1855 that Sedillot [3] performed the second recorded intrapleural operation. In an exhaustive review of the literature from then until 1898, Parham [4] was able to collect twenty-six cases in which resections were performed without opening the pleural cavity, and fifty-four, including two of his own, in which it was opened. Of twenty-three additional cases of resection of the sternum, pneumothorax resulted in six. In one instance, both pleural cavities were opened, with resulting bilateral pneumothorax. The patient recovered. In considering the effect of pneumothorax, Parham classified forty-one selected cases into three groups: (1) those in which little or no disturbance followed opening of the pleural cavity, sixteen cases; (2) those in which there was moderate disturbance, ten cases, and (3) those in which there was marked disturbance, ten cases. He concludes that the size of the opening and the duration of the open pneumothorax are the most important factors in producing symptoms. He found that the respiration was interfered with to some extent in all, and that seven of the patients suffered severe collapse. In cases of extensive resection involving adjacent structures, such as the diaphragm and pericardium, he accredited the serious symptoms to the prolongation of the operation rather than to the severity of the procedure.

In 1898, Parham used the differential pressure method of Fell-O'Dwyer in operating on a patient with chrondrosarcoma. He employed positive pressure to inflate the lung, which was then sutured to the parietal pleura, after which he dispensed with the apparatus. A thorough search of the literature has brought to light reports of sixty-seven cases of tumor of the chest wall in which operation was performed since Parham's first patient was operated on under differential pressure. This includes twenty-eight cases reported by Lund,[5] in 1913, and one case in which he operated under intratracheal insuffla-

3. Sedillot, quoted by Parham: Footnote 1, second reference.

4. Parham, F. W.: Thoracic Resection for Tumors Growing from the Bony Wall of the Chest, New Orleans, 1899.

5. Lund, F. B.: Sarcoma of the Chest Wall, Ann. Surg. **58**:206-217, 1913

tion. The case reports of Gross,[6] Stukkei,[7] Hervy,[8] Degorce,[9] Palleroni,[10] and Zschucke [11] unfortunately were not available for this study.

The records of the Mayo Clinic since 1910 contain the histories of forty-nine patients with tumors of the bony chest wall. A complete report of these cases has been published recently.[12] Fifteen have been included in this study as having a bearing on the theme. With the fifty-eight cases from the literature, the total is eighty-two cases.

OPERATIONS UNDER DIFFERENTIAL PRESSURE

Eighteen (about 20 per cent.) of the eighty-two patients were operated on under differential pressure anesthesia. The type of differential pressure apparatus used was the Fell-O'Dwyer apparatus in one operation; Brauer's positive pressure chamber in four operations; Sauerbruch's negative pressure chamber in six, and Murphy's chamber in one operation. Intratracheal insufflation was used in four operations and intrapharyngeal insufflation in two.

Chloroform anesthesia was used in five operations, ether in eight, nitrous oxid and oxygen in one, and the anesthetic was not mentioned in four.

The resection was performed for chondroma in three, for sarcoma in nine, for endothelioma in one, for recurrent carcinoma following amputation of the breast in four, and for chronic inflammation in one.

The opening in the chest wall was stated or was suggested by the context to be small in one case (4 cm. in diameter); moderately large ("Handteller Grösse") in eight, and large (10 cm. by 18 cm.) in six. In one case, the size of the opening could not be determined, and in two, an opening was not made in the pleura.

The symptoms referable to the opening of the pleural cavity were weak, rapid pulse, and disturbed respiration in the two cases of Por-

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6. Gross, G.: Sarcomes étendus de la région sterno-claviculaire; exstirpation; autoplastie par glissement et décollement, Rev. méd. de l'est. **45**:497-500, 1913.

7. Stukkei, L. G.: Case of Chondrosarcoma of the Manubrium Sterni, Russk. Vrach. **14**:977, 1915.

8. Hervy, J. M. J.: La chondrectomie (operation de Freund) est-elle une intervention bénigne? Bordeaux, Cadoret, 1915.

9. Degorce, A.: Sarcome de la paroi antéro-latérale du thorax à prolongement intrathoracique, Bull. Soc. méd.-chir. de l'Indo-Chine **5**:160, 1914.

10. Palleroni, G.: Sopra un caso di encondrosarcoma della parete toracica, Clin. mod. **9**:393-396, 1903.

11. Zschucke, J.: Ueber einen Fall von Myxochondrosarkom der Rippe bei einem zwölfjährigen Mädchen, München, Müller and Steinicke, 1912.

12. Hedblom, C. A.: Tumors of the Bony Chest Wall, Arch. Surg. **3**:56-85 (July) 1921.

ter [13] and Payr.[14] In both of these cases the diaphragm was resected, and the symptoms promptly abated. Pleural effusion occurred in one patient as a postoperative complication. Porter's patient died on the fourteenth day, and purulent bronchitis and pneumonia were found at necropsy.

OPERATIONS WITHOUT DIFFERENTIAL PRESSURE

Sixty-four patients were operated on without differential pressure. The ribs and adjacent structures included in the resection are listed in Table 1.

Chloroform was used for fifteen patients, gas and ether for one patient, and ether for fourteen patients; the anesthetic for the others was not mentioned. Pneumothorax was produced in forty-three of the patients, in two bilaterally. In the remaining twenty-one patients, the pleura was not opened, or there were extensive adhesions.

TABLE 1.—EXTENT OF RESECTION

	Cases	Structures Resected with Ribs							
		Clavicle and Sternum	Diaphragm	Cartilages	Diaphragm and Peritoneum	Diaphragm Pericardium and Lung	Sternum	Lung	Pericardium
One rib.....	11	2	1	..	..	..	..	..	1
Two ribs.....	20	4	2	..	1	..	..	..	..
Three ribs...	18	..	3	..	1	..	1	..	..
Four ribs.....	15	..	3	..	..	1	..	1	..
Five ribs.....	1	..	..	..	..	..	..	..	..
Sternum.....	11	5	..	2	..	..	..	..	..
Vertebra.....	1	..	..	..	..	..	..	..	..
Structure not mentioned..	7	..	..	..	..	..	..	..	..
Total.....	84	11	9	2	2	1	1	1	1

In the forty-three cases in which the pleural cavity was opened without differential pressure with resulting pneumothorax, the opening was stated or suggested to be small in nine, moderately large in three (about 7 cm. in diameter), and large in twenty-three. In the other cases the size of the opening was not mentioned. In several, the opening was so large that "both hands could be introduced at once into the pleural cavity."

It may be noted in Table 2 that of the forty-three patients in whom pneumothorax was produced there were symptoms referable to it in nine, and there were no symptoms in twenty-six. Symptoms were not mentioned in eight. Postoperative symptoms were designated as shock

13. Porter, C. A.: Two Cases of Extensive Thoracic Resections: The First for Enchondroma of the Ribs, the Second for a Closed Tuberculous Empyema of Many Years' Duration, Boston M. & S. J. **159**:861-864, 1908.

14. Payr: Fibrosarkom der Brustwand, Deutsch. med. Wchnschr. **37**:1147, 1911.

in nine; there were no symptoms in eighteen, and no mention of symptoms was made in sixteen. Of the patients without pneumothorax, there was postoperative shock in three, no symptoms in ten, and no mention of symptoms in eight. Table 2 shows, therefore, that while the majority of the patients with pneumothorax do not have marked symptoms referable to it, and only a very small percentage have symptoms at the time of operation, the incidence of postoperative shock is considerably greater if pneumothorax is produced. That this is largely due to the relatively greater extent of the operation on the latter is

TABLE 2.—Symptoms at the Time of Operation and After Operation

	Patients Operated on With Differential Pressure Anesthesia	Patients Operated on Without Differential Pressure Anesthesia	
	Without Pneumothorax	With Pneumothorax	Without Pneumothorax
Shock at the time of operation	3	5	..
Shock after operation	1	9	3
Cyanosis at the time of operation	..	3	..
Cardiac collapse at the time of operation	..	1	..
No symptoms at the time of operation	6	26	10
No symptoms after operation	7	18	10
Symptoms at the time of operation not mentioned	9	8	11
Symptoms after operation not mentioned	10	16	8
Total number patients having symptoms at the time of operation	18	43	21
Total number patients having symptoms after operation	18	43	21

TABLE 3.—Relation of Symptoms to Size of Pleural Opening

Size of Opening	No Symptoms	Slight Symptoms	Marked Symptoms	Symptoms not Mentioned	Total
Small	4	1	..	4	9
Moderate	1	2	..	..	3
Large	14	2	4	3	23
Total	19	5	4	7	35

apparent from the fact that of the nine patients with marked shock after operation six had resections of adjacent structures, namely, the pericardium, the diaphragm, and in one case, the lung.

Table 3 shows that in five cases in which the opening into the pleural cavity was small, no symptoms were present in 80 per cent.; in twenty in which the opening was large, no symptoms occurred in 70 per cent., and marked symptoms were present in only 20 per cent. In the seven cases in which the opening was very large, there were no symptoms in two, slight symptoms in two, and marked symptoms in three. In the three with marked symptoms, the diaphragm was also resected in two. After suture the symptoms subsided.

Sufficient data were not forthcoming on which to base any observation as to the relation between the length of time the pleural cavity

was opened and the relative incidence of symptoms. The depth of anesthesia, the relative conditions of the patients, and the position on the operating table are additional factors which produce uncertainty in attempts to estimate the direct relationship of the pneumothorax and the symptoms. In the absence of symptoms, however, it may be assumed that the pneumothorax was relatively harmless.

In several cases in the Mayo Clinic series, it was well shown that the extent of the operation plays a large part in the production of shock entirely independent of pneumothorax. Several of the patients were practically pulseless after leaving the operating room following

TABLE 4.—Postoperative Complications in Relation to Pneumothorax

	Patients Operated on with Differential Pressure Anesthesia	Patients Operated on Without Differential Pressure Anesthesia	
		With Pneumothorax	Without Pneumothorax
Bronchitis	..	..	1
Pneumonia	1	2	..
Pleurisy with effusion	1	4	..
Empyema	..	5	..
Pulmonary congestion	..	1	..
Anuria	..	..	1
Total	2	12	2

TABLE 5.—Postoperative Mortality

Cause of Death	Patients Operated on with Differential Pressure Anesthesia	Patients Operated on Without Differential Pressure Anesthesia	
		With Pneumothorax	Without Pneumothorax
Pneumonia	1	1	..
Empyema	..	3*	..
Shock	..	2	..
Anuria	..	..	1
Not given	..	1*	..
Total	1	7	1

* Double pneumothorax in one case.

resection for large tumors without opening of the pleural cavity. Loss of blood was slight, and in no case was the operation very long. Some of these patients were in fairly good condition; others were poor surgical risks. A two-stage or three-stage operation was performed in the latter cases. That a resection of the structures of the thoracic wall in itself produces shock is demonstrated in certain cases of radical amputation of the breast. Considerable shock may result in a patient who was a relatively good operative risk.

From Table 4, it will be observed that 11 per cent. of patients operated on with differential pressure anesthesia developed complications, while 28 per cent. of patients operated on without differential pressure anesthesia and in whom pneumothorax occurred developed

complications. Pleural effusion, both serous and purulent, is of much greater incidence in cases in which pneumothorax is produced.

Table 5 shows that one death occurred on the fourteenth day in a patient operated on under differential pressure anesthesia. This case was reported by Porter who considered the differential pressure anesthesia largely contributory to the unfavorable outcome. One of the patients in the Mayo Clinic died of pulmonary edema the second day following operation for intrathoracic tumor under intratracheal anesthesia. Seven deaths followed operation in the cases in which differential pressure was not used, and in which pneumothorax occurred. In two of these, however, a bilateral pneumothorax had been produced. The mortality rate was about 5.5 per cent. for the first group and 16.3 per cent. for the second. If the cases of shock, which may have been due to other causes, are subtracted, the mortality rate drops to about 11 per cent. Pneumothorax did not occur in the patient with anuria.

COMMENT

The cases presented and the results obtained have significance in relation to the question of the actual immediate risk of open operative pneumothorax, and in relation to postoperative complications. It is obviously not only possible but reasonably safe, so far as the immediate risk to the life of the patient is concerned, to open wide the pleural cavity without differential pressure anesthesia. The experience of many operators has shown that in the majority of patients in whom a large opening of the pleura has been produced, with collapse of the lung, symptoms have been absent or slight. Furthermore, it is always possible to convert a large opening into a small opening, or completely to close the opening by drawing together the skin edges or by covering the opening with a wet towel. Experience has also seemed to show that traction on the lung will promptly relieve alarming symptoms referable to inefficient respiration. Whether the apparently slight effect produced by wide-open pneumothorax in so large a proportion of cases is due to a previous thickening of the mediastinum or to partial adhesions of the lung may be questioned. It is certain that there was massive collapse of the lung in many cases; but even granting the presence of a thickened mediastinum and possibly adhesions, and if it is further admitted that patients without thickened mediastinums and without adhesions would become asphyxiated by a large opening, the objection to operating without differential pressure anesthesia in such cases would be largely overcome by the fact that when alarming symptoms are presented it is a simple matter to convert the open pneumothorax into a closed pneumothorax.

From a technical standpoint, however, an operation under differential pressure anesthesia can unquestionably be performed with greater assurance, less disturbance to the patient, and greater comfort to the surgeon. The impracticability to the average operator of differential pressure anesthesia chambers and the technical difficulties incident to the use of intratracheal insufflation and of other apparatus must be taken into consideration.

A study of these cases in relation to postoperative complications, with their increased mortality, indicates that the increased occurrence of complications furnishes the greatest support for the use of differential pressure anesthesia in resections for tumors of the chest wall. It has been demonstrated clinically and experimentally by Noetzel,[15] Tiegel,[16] Burkhardt,[17] and others, that pneumothorax renders a pleural cavity less resistant to infection. Robinson and Sauerbruch [18] showed that a sterile pleural effusion may develop, apparently due to the lack of contact between the pleurae. The presence of a dead space would also seem to contribute to a postoperative infection. The tendency to localization, as in the peritoneal cavity and, to some extent, in the normal pleural cavity, is absent. The aspiration of the air into the pleural cavity at operation probably also increases the risk of pulmonary infection. This could be largely obviated, however, by the use of gauze protection, as in abdominal surgery.

Empyema was the most potent cause of death in this group of cases; and it is reasonable to believe that the presence of pneumothorax at least contributed to the development of this complication. Therefore, from the standpoint both of maximum safety to the patient and of technical facility, differential pressure anesthesia is preferable in any case in which the thorax is likely to be opened wide and to remain open for some time. The greatest argument in favor of differential pressure anesthesia seems to rest in the fact that the development of postoperative complications, particularly pleural effusion, is apparently lessened by its use. This advantage may be gained, however, possibly equally well by some method of insuring an inflation of the lung at the end of the operation. In view of the advantages of local anesthesia for a preliminary incision, rib resection,

15. Noetzel, W., quoted by Sauerbruch, F.: Die Chirurgie der Brustorgane, Berlin, Springer **1**:396, 1920.

16. Tiegel, M.: Ueber operative Pleurainfection und Thoraxdrainage, Arch. f. klin. Chir. **98**:1022-1058, 1912; Experimentelle und klinische Studien über die postoperativen Komplikationen bei Eingriffen in der Brusthöhle, Beitr. z. klin. Chir. **80**:128-156, 1912.

17. Burkhardt, quoted by Sauerbruch: Footnote 15, second reference.

18. Robinson, S., and Sauerbruch, F.: Untersuchungen über die Lungenexstirpation unter vergleichender Anwendung beider Formen des Druckdifferenzverfahrens, Deutsch. Ztschr. f. Chir. **102**:542-560, 1909.

and so forth, a combination of local anesthesia with some type of differential pressure anesthesia apparatus would make possible the inflation of the lung at the end of the operation before closure. This method was used in one case in the series in the Mayo Clinic and represents a maximum of simplicity and of operative and postoperative safety to the patient. A simple intrapharyngeal insufflation anesthesia by the use of a gas and oxygen apparatus achieves this result.

The foregoing deductions seem justified by the actual experience of many surgeons with different methods and by my experience with ten patients, some of whom were operated on with differential pressure anesthesia, and others without it. Although I have not entered into a discussion of the pathologic physiology of pneumothorax, I wish to point out that the explanation of the phenomena incident to pneumothorax is not simple.

The work of Graham and Bell,[19] showing that in the normal thorax the pleural cavities function as one and that a change in pressure in one cavity is immediately transmitted to the other, seems fundamental to the study of the problem. This principle accounts for the prompt relief that results on converting an open pneumothorax into a closed pneumothorax, and for the relief obtained by traction on the exposed lung. It remains to be shown, however, why such a large proportion of patients do not develop alarming symptoms when the thorax is opened wide.

The symptoms produced in open pneumothorax are referable in the last analysis to disturbed circulation, to deficient aeration of the blood, and, possibly in some cases, to a pleural reflex. The return of the blood to the right side of the heart is dependent on the force of the heart's action through the capillaries, on the valve action in the veins, on the muscle tone as pointed out by Mann,[20] and on the aspirating effect of the respiratory pump. In open pneumothorax, this aspiratory action is lost, and cyanosis and engorgement of peripheral veins develop. Deep anesthesia, resulting in loss of peripheral tone, further hampers venous return. Deficient venous return results in a lowered output from the heart, increased pulse rate, and, eventually, in a fall of blood pressure and shock. A positive pressure anesthesia apparatus provides for aeration of the blood, but does not furnish a substitute for the aspiratory action of normal respiration. Sauerbruch holds that, on the contrary, positive pressure impedes the circulation in the lungs.

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19. Graham, E. A., and Bell, R. D.: Open Pneumothorax: Its Relation to the Treatment of Empyema, Am. J. M. Sc. **156**:839-871 (Dec.) 1918.

20. Mann, F. C.: Personal communication.

Considerations which bear on the aeration of the blood are the relative amounts of blood passing through a collapsed lung as compared with that passing through a normal lung, the relative importance of the paradoxic respiration in the collapsed lung, the part played by the diaphragm, and the possible influence of disturbed nerve function. Other problems relate to the increased susceptibility of the pleural cavity in pneumothorax, to effusion and infection, and to the possible part of a pleural reflex in the sudden onset of symptoms incident to the abrupt collapse of the lung.

FRACTURE-DISLOCATION OF THE SPINE

TREATED BY FUSION

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The cases reported herewith are from the service of the New York Orthopedic Dispensary and Hospital.

Of these twenty-two cases of fracture-dislocation of the spine, one was in the cervical region, two were in the dorsal region, two in the dorsolumbar region, and seventeen in the lumbar region. Of the last named, eleven were of the fifth lumbar vertebra.

There was a definite history of severe traumatism in the cervical case, in the two dorsal cases, in the two dorsolumbar cases, and in twelve of the lumbar cases. In five of the last, the injury had occurred in childhood. The symptoms in three cases, except those of short duration occurring immediately after the injury, did not appear until adult life when ossification of the vertebrae was complete. In one instance, Case 18, that of a motorcycle accident, the traumatism was severe; but the only conscious injury at the time was of the leg, although at operation, two years later, it was found that the patient had an ununited fracture of the four laminae of the third and fifth lumbar vertebrae. Another patient, Case 22, had an ununited fracture of both pedicles of the fifth lumbar vertebra, six years after the accident. In another instance, Case 16, the injury occurred at the age of 9; and at operation, fourteen years later, an ununited fracture of the lamina of the fourth lumbar vertebra, left side, was found.

In one case there was a history of slight injury, and in four cases no history of injury. In the four cases with no history of injury the fifth lumbar vertebra was involved, which, considering the fact that of the whole number seventeen were of the lumbar spine, and eleven of these of the fifth lumbar vertebra, emphasizes two points of importance: first, that the lumbar spine is the most susceptible to fracture, and, second, that the fifth lumbar vertebra is the one most frequently fractured. The explanation of these facts is suggested in the following considerations: The lumbar spine is subjected to great strain in all trunk movement on the pelvis, being exercised through wide arcs of motion by very great muscle pull, especially in persons with heavy muscles, engaged in laborious occupations requiring heavy lifting. The angle of the lumbar spine with that of the sacral places all of the lumbar vertebrae at a disadvantage, while the fifth, the end of the mobile spine, articulating with the immobile sacrum, is at the point of greatest

strain. Its position becomes more precarious as, and in the measure that the variation which takes place in this angle (which is about 40 degrees, from 100 to 140) approaches a right angle. The insecurity of the fifth lumbar vertebra is also increased by the variation which is often seen in the shape, size and planes of the articulation of the lateral processes of the fifth and first sacral vertebra, making inconstant and insecure their effect in checking movement and in stabilizing the fifth lumbar vertebra.[1]

It is debatable whether or not any considerable degree of displacement of a lumbar vertebra can take place without a fracture, or the disintegration, of these articulations by disease. (In Case 1, the patient had disintegration of these processes.) Should this happen, it will, in all probability, be of the fifth lumbar vertebra. It is also questionable whether in cases in which the angle of the lumbar vertebra with the sacral spine approaches a right angle (marked lordosis), there may not be sufficient strain at the lumbosacral junction to cause pain, thereby explaining some cases of chronic backache, otherwise obscure.

Four patients with displacement of the fifth lumbar vertebra had imperfect first sacral arches. This defect may impair the ligamentous stability of the joint.

In all instances in which the patient had a forward displacement of the fifth lumbar vertebra, the spinous process was felt to be less prominent. In some of these cases, the lordosis was increased and in others it was not, depending, it would seem, on whether or not there was also a forward displacement of the fifth lumbar vertebra at its articulation with the fourth lumbar vertebra. In Case 6, the displacement at the fourth lumbar vertebra was equal to that at the first sacral vertebra, and consequently the lordosis was not increased. In two instances of backward displacement of the fifth lumbar vertebra, the spinous process was more prominent.

There was direct contact of two or more spinous processes in seven of the lumbar cases and marked limitation of extension of the lumbar spine. In all trunk movement, the impingement of these bones on one another caused distressing pain.

In one instance, Case 14, the constant posture was that of forward bending and inclination to the left side. The fracture occurred at the age of 15, although the symptoms did not appear until adult life, since which time they had been constant and distressing when the patient was in an upright position. She had been subjected to every form of treatment, especially for sacro-iliac relaxation, without benefit, except for relief when lying in bed. It was finally believed that she was

1. Mills, Nathaniel: Congenital Malformations of the Vertebra, Boston M. & S. J. **184**:659-666 (June 23) 1921.

suffering from a psychoneurosis and she was sent to a sanatorium for treatment. She had mobility at the sacro-iliac joints, as demonstrated by mobility at the pubis; but that this mobility caused no symptoms, as is often the case, is demonstrated by the fact that her relief since operation has been complete, although the sacro-iliac mobility is unchanged.

In thirteen cases, there was fracture of the body and of the processes, and in nine cases, all lumbar, fracture of the processes only. In all of the dorsal cases, there was fracture of the body; only one patient (Case 12) having displacement as well. The explanation of this fact is found in the greater stability of these articulations, their limited motion and the protection of the thorax. In one instance, Case 17, the patient had six lumbar vertebrae. The sixth was fractured and displaced forward, with contact between the spines of the fifth and sixth lumbar vertebrae.

In six instances (Cases 6, 9, 12, 14, 16 and 22), the fractures occurred in childhood, although the symptoms did not appear in four of them until adult life, when ossification was complete. Of the two remaining cases, one patient, 18 years of age (Case 22), was found to have an ununited fracture of the pedicles of the fifth lumbar vertebra at operation six years after injury, the symptoms having been continuous. The other (Case 12) was a child of 5 at the time of operation, two and one-half months after injury.

There was no evidence of nerve root or cord injury in twenty-one cases. One patient (Case 19) had impairment of the sphincters, exaggerated patellar reflexes, and weakness of the legs for six weeks after the injury. In the cervical case, the patient had a great deal of pain in the neck and shoulders, with a protective posture of the head. In the dorsal and dorsolumbar cases, there were sensations of weakness, with more or less deformity, and one patient (Case 9) had a marked scoliosis. In the lumbar cases, the patients complained of pain and weakness in the lower back and of pain in one or both legs, sciatic in character. Many of these patients had the protective posture and limitation of motion of Pott's disease. In all of the cases, the patients were seriously handicapped by the severity of their symptoms, while some of them were unable to pursue any active occupation. In only three cases of the whole series (Cases 19, 20 and 21), all of which were recent fractures, had a diagnosis of fracture been made. In the other nineteen cases, the fractures had occurred from one to twenty-five years previously.

The shape of a vertebra and its relation to other structures make it difficult, or perhaps impossible, to secure a roentgenogram that will give exact and complete knowledge of the fracture. This is certainly true in cases studied long after the fracture has occurred. In all of

these cases, the patients were subjected to the most careful roentgen-ray study by anteroposterior, lateral, and stereoscopic roentgenograms. The lateral roentgenograms were especially important in differentiating fractures from disease, by showing clearly the condition of the bodies and the intervertebral disks. They were also important in showing accurately the degree of displacement. In every case, the operation revealed injury or displacement of bone not shown by the roentgen ray. For instance, in one case, the patient (Case 18) had ununited fractures of the laminae of the third and fifth lumbar vertebrae on both sides; another (Case 22) had ununited fractures of the pedicles of the fifth lumbar vertebra, six years after the injury, and another (Case 16), an ununited fracture of the lamina of the fourth lumbar vertebra on the left side, fourteen years after injury.

The roentgen ray revealed in every case a degree of abnormality of bone that, associated with the symptoms, justified operation. The operative findings made it evident that the fracture-dislocation had produced a profound and permanent change in the articulations of the vertebrae involved; that the symptoms had been caused by the mobility of these altered joints and ununited fractures and by the influence that their need of protection had in stimulating a protective limit in the joints adjacent, and that the severity and duration of the symptoms depended on the mobility of the region involved and the amount and character of the displacement and injury to the bone.

Since it is impossible to restore these joints to normal, the elimination of motion which takes place in them would seem to offer the only chance of securing complete and permanent relief. To this end, the fusion of the articulating bones is necessary. This has been successfully accomplished in all of these cases by the operative method which has been used at the New York Orthopedic Hospital in several hundred cases of tuberculosis of the spine and of scoliosis. As former descriptions of the technic have been misunderstood, it is perhaps well to describe the operative procedure again.

TECHNIC

An incision is made through the skin and subcutaneous tissue, from above downward, exposing the tips of the spinous processes of the vertebrae to be fused. The periosteum over the tips of these processes is split longitudinally, and, with a periosteal elevator, pushed to either side, leaving them bare. The periosteum and interspinous ligament in turn are still farther split and pushed forward a short distance from each spinous process, as two lateral halves, gauze packs being inserted to prevent oozing. The dissection is carried farther and farther forward upon each vertebra, in turn, until the spinous processes, the posterior surfaces of the laminae and the base of the transverse

processes, are bared, thereby exposing the ligamentum subflava attached to the margins of the laminae and the articulations of the lateral processes.

The ligament is removed from the laminae with a curet, and the articulation of the lateral processes is destroyed in order to establish bone contact at this point. With a bone gouge, a substantial piece of bone is elevated from the adjacent edges of each lamina, of half its thickness and of half its width. The free end of the piece from above is turned down to make contact with the lamina below, and the free end of the piece from the lamina below is turned up to make contact with the lamina above.

Each spinous process is then partially divided with bone forceps and broken down, forcing the tip to come into contact with the bare bone of the vertebra below. The spinous process of the last vertebra below should be turned up to bring about contact with the next above. As the spinous processes of the lumbar region are wide, it is sometimes practicable to split them, turning one half up and the other half down. Thus is established contact of abundant cancellous bone at the articulations of the lateral processes, laminae and spinous processes. The periosteum and ligament, which together have been pushed to either side and lie practically as an unbroken sheet, are brought together in the middle with interrupted sutures of ten-day chromic catgut. The subcutaneous tissue is then closed with a continuous suture of plain catgut; the skin wound is closed with sutures of ten-day chromic catgut, and sterile dressings and an immobilizing brace or plaster are applied.

The dissection may be made in a practically dry field, without injury to the muscles, if it is subperiosteal and if a free use is made of gauze packs. Only in an operative wound that is free from hemorrhage can the operator see to exercise the care necessary for thorough work. Not only the baring of the bones may be complete, but the periosteum may be separated from them in a practically unbroken sheet and without disturbance of its relation to the surrounding tissues and blood supply. The greatest care should be exercised in this dissection, since it is of primary importance, as the area of fusion is measured by its extent and thoroughness. After the bones are bared, they may be treated as indicated above, or in any manner which establishes their contact and stimulates bone formation. With the closure of the periosteum, what is practically a tube of periosteum is formed, with its abundant blood supply undisturbed, filled with healthy, living cancellous bone, lying in continuous contact. This situation is entirely consistent with the physiologic laws of bone growth; it furnishes a great stimulus to their operation, and insures a fusion of the lateral processes, the laminae and the spinous processes.

In each of the cases reported herewith, the fusion was made to include at least one healthy vertebra above and one below the injured vertebra. The patient was kept in bed for eight weeks and required to wear a support for from two to four months longer. The support in each instance was of the Taylor spine brace model, except in the lumbar cases, when it was shortened above to extend only to the tip of the scapula, and lengthened below to grasp the pelvis.

REPORT OF CASES

CASE 1.—Dr. S., aged 43, short, heavy set and of good muscular development, for many years had had an arthritis, involving the knees, hips, shoulders and lower spine. During the previous year, the pain in the back had become very severe; and for three months, a slipping sensation had been present at the lumbosacral joint. This was so painful that he was obliged to discontinue his work.

Examination.—The knees and hips were slightly flexed, and there was a marked exaggerated lordosis. The flexibility was greatly impaired; and on certain movements, a slipping sensation could be palpated at the lumbosacral junction. Roentgen-ray examination revealed an anterior displacement of the fifth lumbar vertebra on the sacrum.

Operation.—March 30, 1916, fusion extending from the third lumbar vertebra to the sacrum was accomplished. The articular processes of the fifth lumbar vertebra and the sacrum were found to have been disintegrated by the arthritis, permitting the forward displacement of the fifth lumbar vertebra on the sacrum.

Present Condition.—The posture is much improved, and the patient is entirely relieved of the symptoms for which the operation was performed. He has resumed the active practice of his profession. This case, although, strictly speaking, not a case of fracture-dislocation, was such a case in every essential.

CASE 2.—S. O., a laborer, aged 48, large, powerful and heavy set, fell from a ladder in October, 1918, since which time he had had severe pain in the back, with peculiar sensations in both limbs, especially the right.

Examination.—This demonstrated a protective posture, similar to that of Pott's disease, with a rounded kyphos in the dorsolumbar region, the apex of which was at the eleventh dorsal vertebra. There was some pain on attempted bending, marked limitation of motion, and slightly increased patellar reflexes, with sensations of paresthesia. The roentgen ray disclosed compression fracture of the eleventh and twelfth dorsal vertebra, with an apparently normal intervertebral cartilage.

Operation.—March 12, 1919, fusion extending from the tenth dorsal to the second lumbar vertebra was accomplished. The spinous process of the tenth dorsal vertebra was found to be broken off.

Present Condition.—The patient is completely relieved and is working daily.

CASE 3.—M. C., a ship steward, aged 44, fairly tall, slender and wiry, fell 40 feet (12 meters) from a gangplank in January, 1917, fracturing his legs and injuring his spine. Since that time he had had increasing pain and stiffness in the back and what was diagnosed as double sciatica.

Examination.—The posture was protective, with fair flexion, but there was marked muscular spasm on lateral motion and extension. There was slight

inclination to the right and tenderness over the lower lumbar spine and sacrum. The patellar reflexes were normal. The roentgen ray showed compression fracture of the fourth and fifth lumbar vertebrae, most marked on the right. List and rotation were especially sharp at the sacrum.

Fig. 1 (Case 3).—Compression fracture of the fifth lumbar vertebra, with lateral displacement.

Operation.—Jan. 19, 1918, fusion, from the second lumbar vertebra to the sacrum, was accomplished. The fourth and fifth lumbar vertebrae were found to be distinctly compressed, owing to crushing of the bodies and fracture of the articular processes.

Present Condition.—The patient is completely relieved and has resumed normal activities.

CASE 4.—T. K., a foundry worker, aged 33, heavy, strong and muscular, a year before examination began having pain in the back and legs. This grew

Fig. 2 (Case 6).—Anterior displacement of the fifth lumbar vertebra without suggestion of lesion in anteroposterior roentgenogram.

steadily worse, and a few months before he was seen here, his back had become crooked. There was no history of severe injury.

Examination.—The posture was very protective, with a severe inclination of the trunk to the left. The spine was held rigidly in this position. The

patellar reflexes were greatly exaggerated. The roentgen ray revealed complete sacral ossification, and what appeared to be a collapse of the lower left side of the body of the fifth lumbar vertebra and one-fourth inch (6.4 mm.) anterior displacement of this body on that of the fourth lumbar vertebra. Its relation to the sacrum could not be seen.

Fig. 3 (Case 6).—Anterior displacement of fifth lumbar vertebra.

Operation.—July 10, 1918, fusion from the third lumbar to the second sacral vertebra was accomplished. There was incomplete ossification of the first sacral arch, with motion between this vertebra and the second. The fifth lumbar vertebra had slipped forward between the fourth lumbar vertebra and the sacrum, fracture of the articular processes allowing its displacement.

Fig. 4 (Case 8).—Anterior displacement of the fifth lumbar vertebra, with incomplete ossification of the sacral and fifth lumbar arches.

Present Condition.—There is complete relief from all symptoms. The patient is practically erect and is working.

CASE 5.—J. S., a prize-fighter, aged 22, thick set and of good musculature, when lifting a heavy timber in March, 1920, experienced a sudden sharp pain in the lower part of the back and in the right leg. This had persisted and was gradually becoming more severe.

Fig. 5 (Case 8).—Anterior displacement of the fifth lumbar vertebra. Impaired ligamentous strength suggested as a factor in this case.

Examination.—The posture was protective, the patient especially favoring the right leg. The trunk was inclined to the left, with free movement in this direction. All other motions were limited by pain and spasm, flexion, especially, often causing sharp pain which extended as far down as the right heel. The roentgen ray revealed incomplete ossification of the first sacral arch, sharp

left angulation between this segment and the fifth lumbar vertebra, and, to a lesser extent, between the fourth and fifth lumbar vertebrae; a slight collapse of the fifth lumbar vertebra, with an anterior and right displacement.

Operation.—Sept. 17, 1920, fusion, from the third lumbar vertebra to the sacrum, inclusive, was accomplished. The fourth lumbar spinous process was displaced downward and to the right of the fifth lumbar vertebra, which was forward and compressed between the fourth lumbar vertebra and the sacrum. Before operation the patient was placed in straight traction, following which there was much relief. One week after operation, he was again placed in traction, under which something "snapped" in his back, giving him complete and immediate relief.

Present Condition.—The patient is completely relieved and has taken up the fighting game again.

CASE 6.—W. V. L., a business man, aged 31, large, well built and heavy set, when a child fell from a trapeze, alighting in a sitting position. There had been more or less pain, stiffness and weakness since that time, with a marked increase in symptoms, especially on lifting, shortly before being examined here.

Examination.—The posture was only slightly protective; but the patient did not use the trunk of his body well. The fourth lumbar spinous process was very prominent, with a lost lordotic curve. He had compensated above and had a slight inclination to the right. There was a moderate limitation of motion in all directions, with some pain on extension of the lumbar spine. The roentgen ray revealed one-fourth inch (6.4 mm.) anterior displacement of the fifth lumbar vertebra on the fourth lumbar vertebra and a one-half inch (12.7 mm.) displacement of the same on the sacrum. The fifth lumbar vertebra was tilted posteriorly down and the fourth tilted up, creating a wide gap between the fourth and fifth spinous processes and contact between the fifth spinous process and the sacrum.

Operation.—May 25, 1920, fusion extending from the third lumbar vertebra to the sacrum, inclusive, was accomplished. The fifth lumbar vertebra was found to be far forward between the fourth lumbar vertebra and the sacrum, while the fourth lumbar vertebra was posterior in its relation even to the sacrum. The laminae of the fourth overrode the fifth so far that they almost came in contact with the sacrum, although this vertebra was tilted up from the posterior position. There was contact with spur formation between the third and fourth spinous processes. The third, as a whole, was tilted slightly to the right, with a corresponding relation of the laminae.

Present Condition.—Complete relief followed operation and the patient has resumed his normal activity, playing tennis, golf, etc.

CASE 7.—D. S., a stock clerk, aged 20, small and fairly thick set, in September, 1919, complained of increasing pain in the lower part of the back and in the thighs. There was no history of accident.

Examination.—This revealed a rigid military posture, with slightly exaggerated lordosis. No motion was demonstrable except forced extension, which was painful. The right patellar reflex was increased. The roentgen ray revealed a slight left lateral deviation of the fourth lumbar vertebra, with anterior displacement of one-half inch (12.7 mm.) on the fifth and one-fourth inch (6.4 mm.) on the third lumbar vertebra. The spinous processes of the third and fourth lumbar vertebrae were in contact and sacral ossification was incomplete.

Fig. 6 (Case 12).—Compression fracture and displacement suggesting Pott's disease.

Operation.—July 9, 1920, fusion from the third lumbar vertebra to the sacrum, inclusive, was accomplished. Incomplete ossification of the first sacral arch was found, with good relations, however, between it and the fifth lumbar vertebra, although the articulations were poorly formed and very little motion could be demonstrated. The fourth lumbar vertebra extended so far forward on the fifth that the articular facets had almost completely slipped by. New ones had formed between the laminae themselves; and, owing to the upward tilt, there was contact between the spinous processes of the third and fourth lumbar vertebrae.

Present Condition.—There is complete relief and the patient is working daily.

CASE 8.—D. R., a policeman, aged 25, large, heavy set, with well developed mucles, when making an arrest in August, 1919, had been injured by the door of a taxicab which was slammed against his back. He had had severe pain and stiffness ever since.

Examination.—The posture was protective, with the lumbar spine held rigidly by muscular spasm. Any attempted motion caused pain. The sacro-iliac joints, especially the right, were tender, and there was slight exaggeration of the patellar reflexes. He wore a belt for a time, which gave partial relief. A roentgenogram showed attempted sacralization of the fifth lumbar vertebra, with incomplete ossification of the sacral and fifth lumbar arches. There was a one-fourth inch (6.4 mm.) anterior displacement of the fifth lumbar vertebra on the sacrum and a marked left-sided compression of the body.

Operation.—April 29, 1920, fusion from the third lumbar vertebra to the sacrum, inclusive, was accomplished. The right side of the first three sacral arches was found to be incomplete. The fifth lumbar vertebra was grossly abnormal, in that the lamina on the left side was not fused; and it, with the spinous process, was entirely loose. The right lamina was very short but firmly attached. The entire vertebra was crowded forward slightly and it was distinctly narrowed on the left.

Present Condition.—It is believed that this man's relief would be complete but for the fact that he is endeavoring to secure large compensation. He has been on duty since four months after operation but continues to wear a brace.

CASE 9.—F. B., a physician, aged 26, short, heavy set and powerful, when 14 years of age, fell from a tree, injuring his spine. He had undergone a variety of treatment, but his back had continued to be weak. He was easily fatigued and experienced a more or less constant ache. The deformity which appeared after the accident had increased.

Examination.—There was a slight general inclination to the left, with prominence of that hip. There was a moderately sharp curve to the right, reaching from the eighth dorsal to the second lumbar vertebra. This was in conjunction with a moderate bulging type of kyphosis in the same region. Right lateral flexion and extension were distinctly limited. The roentgen ray revealed a moderate right curve from the eighth dorsal vertebra down, including a slight tilt of the fifth lumbar vertebra. Rotation was very sharp, especially at the first and second lumbar vertebrae. The greatest convexity was at the first lumbar vertebra, owing to marked lateral wedging of this vertebra and of the twelfth dorsal and second lumbar vertebrae. The third lumbar vertebra was only two thirds of its normal size. Laterally, there was an exaggerated dorsal curve in consequence of sharp wedging of the first and second lumbar vertebrae. The spinous processes of the twelfth dorsal and the first lumbar

Fig. 7 (Case 12).—Compression and displacement.

vertebrae were in contact, whereas those of the first and second lumbar vertebrae were widely separated. Rib formation was normal.

Operation.—June 9, 1920, fusion from the tenth dorsal vertebra to the second lumbar vertebra, inclusive, was accomplished. The first lumbar spinous process was large and very prominent, owing to actual posterior displacement of this vertebra on the second. The laminae on the left of the twelfth and first dorsal vertebrae were shorter than normal and so close that fusion had nearly taken place. The articular process of the twelfth dorsal vertebra was far back, as a result of rotation and displacement. The spinous processes were in the same relation as suggested by the roentgen ray. The tenth and eleventh dorsal vertebrae were sharply related to the curve because of the deviation below.

Present Condition.—There is complete relief from symptoms and a marked improvement in posture and the appearance of the trunk. He is active in tennis and all athletics and is now serving an internship.

CASE 10.—D. A., a stationary engineer, aged 47, tall, wiry and with good musculature, about six months previous to his examination in this dispensary, complained of pain in the lower back and down the limbs, especially the right. In the previous few weeks, it had become so severe that walking was difficult. He gained slight relief by bending far forward and supporting himself with a cane.

Examination.—The posture was extremely protective, with the lumbar spine held rigidly in a flat position. Both thighs were held flexed at 160 degrees, although most of his pain was down the right thigh. The fifth lumbar spinous process was more prominent than normal and the distance between it and the fourth was distinctly increased. The patient had a great deal of difficulty in turning over in bed. The roentgen ray revealed a one-fourth inch (6.4 mm.) posterior displacement of the fifth lumbar vertebra on the fourth. Its relation to the sacrum seemed normal.

Operation.—Aug. 4, 1920, fusion from the second lumbar vertebra to the sacrum, inclusive, was accomplished. The fifth lumbar vertebra was posteriorly placed, giving the appearance of having been squeezed back between the fourth lumbar vertebra and the sacrum. The articular processes of the fifth lumbar vertebra had slipped back and upward a trifle. Fusion was extended to the second lumbar vertebra because of contact between all of the spinous processes.

Present Condition.—The patient is completely relieved; he has a normal back contour and stands perfectly erect. He is doing his usual work.

CASE 11.—T. M., a factory worker, aged 28, tall, slender and wiry, July, 1920, complained of pain in the lower spine and left hip region. This had become progressively worse, with increasing stiffness. There had been no severe injury.

Examination.—The posture was protective, with a slightly diminished lordosis and rigidity in this position. He walked in a stooped position, and the left thigh was held slightly flexed. There was tenderness over the left sacro-iliac joint. The roentgen ray revealed slight anterior displacement of the fourth lumbar vertebra on the fifth, and a similar condition of the fifth lumbar vertebra on the sacrum.

Operation.—Oct. 8, 1920, fusion from the third lumbar vertebra to the sacrum, inclusive, was accomplished. The spinous process of the fifth lumbar vertebra was found to be grossly abnormal, in that the superior border extended horizontally back three fourths of an inch (19 mm.) and the posterior border

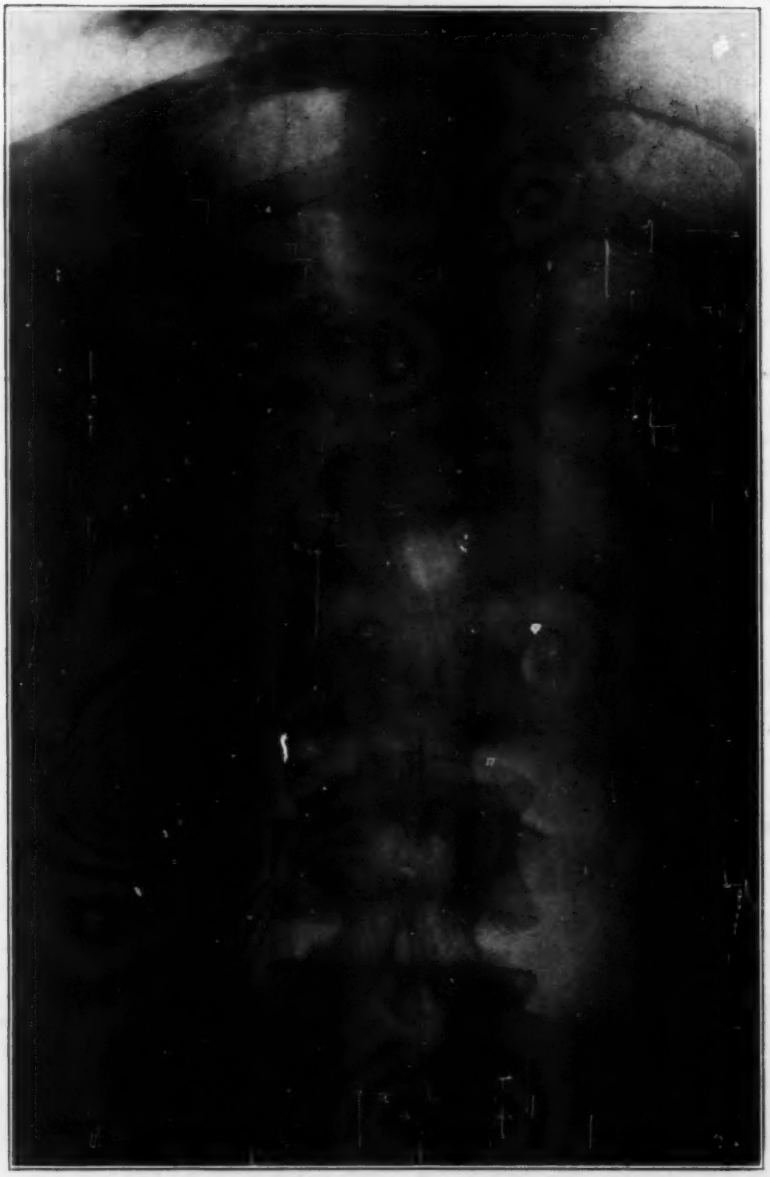

Fig. 8 (Case 13).—Compression fracture of the twelfth dorsal vertebra and first lumbar vertebra.

extended downward 1¼ inches (3.2 cm.), bringing about contact with the second sacral spinous process. The relationship of the articular processes was not determined, although there was distinct displacement, as evidenced by the roentgen ray.

Present Condition.—The patient is actively engaged in his usual work and is without symptoms.

CASE 12.—L. A., boy, aged 5 years, stockily built, was run down by an automobile two and a half months previously, receiving injuries to the spine, head and right knee.

Examination.—The posture was awkward and difficult, with moderate rigidity and muscular spasm. There was a slight left curve, with a marked round back deformity, and great prominence of the first lumbar spinous process. The distance between this process and that of the twelfth dorsal vertebra was much increased. There were no symptoms of cord compression. The roentgen ray revealed a compression fracture of the twelfth dorsal and the first lumbar vertebrae, with a half inch (12.7 mm.) posterior displacement of the first lumbar vertebra on the twelfth dorsal vertebra and wide separation of the spinous processes.

Operation.—Dec. 7, 1920, fusion from the eleventh dorsal vertebra to the first lumbar vertebra, inclusive, was accomplished. The tenth dorsal and the second lumbar vertebrae were exposed and found to be in good position. The first was posteriorly placed on the twelfth dorsal vertebra so far that the articular processes had slipped completely by. The twelfth dorsal vertebra was tilted forward and downward, exposing a large section of the cord membrane.

Present Condition.—There is distinct improvement in the degree of displacement of the vertebrae, much improvement of the deformity and complete relief of symptoms.

CASE 13.—C. G., a cadet at West Point, aged 24, small, slender with fairly good musculature, in October, 1912, fell 30 feet (9.5 meters), alighting on the buttocks. Since that time he had had periods of severe pain in the back, with treatment by bed rest and plaster jackets. For ten months previous to his examination here, he had been wearing a jacket, in spite of which there had been increasing pain, weakness and loss of weight.

Examination.—The posture was moderately protective, with marked muscular spasm and pain, especially on hyperextension. The twelfth dorsal spinous process was prominent as a nodular kyphos, and pressure in this region produced a sensation of nausea. All movements were limited. There was no disturbance of cord function. The roentgen ray revealed a severe compression fracture of the twelfth dorsal vertebra, with a wide gap between the spinous process and laminae of this vertebra and the first lumbar vertebra.

Operation.—Jan. 14, 1921, fusion from the tenth dorsal to the first lumbar vertebra, inclusive, was accomplished. All exposed spinous processes were normal, except the twelfth, which was a mere spike, directed straight back and close up under that of the eleventh dorsal vertebra. There were normal relations between the tenth and the eleventh dorsal vertebrae. The twelfth dorsal vertebra had slipped and was impacted so far up under the eleventh that only remnants of the ligament remained. Considerable absorption had taken place on both sides, but it was more marked on the left. Very little motion was present. The displacement between the twelfth dorsal vertebra and the first lumbar

Fig. 9 (Case 13).—Fracture more clearly outlined.

vertebra was so great that contact was made between the articular processes of the first dorsal vertebra and the transverse processes of the twelfth dorsal vertebra. Fusion had taken place. There was a 1 inch (2.5 cm.) gap between the spinous process of the first lumbar vertebra and what remained of the twelfth dorsal vertebra. This gap was well filled in laterally by the fused processes.

Present Condition.—All symptoms are completely relieved. The patient is in good general condition and his normal activities have been resumed.

CASE 14.—Mrs. H. P., aged 35, well built and rather stocky, when 11 years of age fell from a rock, injuring her spine. She wore a plaster jacket for a short time. She had had increasing pain and weakness in her back and limbs since her eighteenth year. Every conceivable treatment, including long periods of bed rest, had been tried, with only temporary relief. At one time she was placed in a sanatorium for her mental condition. She is the mother of three children.

Examination.—The patient stooped slightly, inclining her body to the left side. Motion in all directions was distinctly limited by lumbar rigidity. Pressure in this region caused pain, which was radiated down the limbs. The roentgen ray revealed slight anterior and right displacement, with left rotation of the fifth lumbar vertebra on the sacrum. The spinous processes of the third, fourth and fifth lumbar vertebrae impinged and there was sacro-iliac relaxation, as indicated by abnormal mobility at the pubic synchondrosis.

Operation.—Jan. 28, 1921, fusion from third lumbar vertebra to the sacrum, inclusive, was accomplished. The third spinous process exhibited a bony exostosis as a result of its rubbing on the fourth lumbar vertebra. The fourth was displaced forward from the fracture and impinged tightly on the fifth lumbar vertebra. The first sacral vertebra was very short and laterally displaced. The laminae of the fifth lumbar vertebra were thrust forward under those of the fourth to an abnormal degree, and there was slight lateral deviation of the spine in a general way, with its greatest convexity at the fourth lumbar vertebra. All the articular processes had slipped slightly in accommodation to the deformity.

Present Condition.—The patient is perfectly free from symptoms, perfectly erect and enjoying normal activity.

CASE 15.—W. B., an architect, aged 61, of stocky build and good muscular development, ten years previously had fallen downstairs, alighting on his neck and forcing the head violently forward. Since that time, there had been constant pain in the neck and shoulders. A year before he was seen, the pain was increased by another accident and at the time of examination was very acute.

Examination.—He held his head and neck in a distinctly protective posture, he was unable to extend his head beyond a point of slight flexion. Rotation was about 75 degrees, whereas flexion was nearly complete. Both were limited by pain, which radiated to the midscapular region. The roentgen ray revealed an impacted fracture of the fourth and fifth cervical vertebrae, with tilting forward and downward of the fourth cervical vertebra in such a manner as widely to separate the spinous processes. Bony callus bridged the bodies of the fifth, sixth and seventh vertebrae, anteriorly. The intervertebral disks were very thin.

Fig. 10 (Case 18).—Compression fracture of the fifth lumbar and first sacral vertebra and anterior displacement of the fifth lumbar vertebra.

Operation.—Feb. 18, 1921, fusion from the fourth to the seventh cervical vertebra, inclusive, was accomplished. There was only slight motion between the fourth and fifth vertebrae and between the fifth and sixth. Motion between the sixth and seventh vertebrae was normal.

Present Condition.—The patient is completely relieved. He continues to be active in professional work, plays golf, etc.

CASE 16.—A. P., a maid, aged 23, stocky and well built, at the age of 9 fell downstairs, injuring her spine, which had been weak since that time. Three years ago she fell from a second story window, after which she suffered severe pain which radiated to the thighs. Recently this had been so severe that she had been compelled to give up work altogether.

Examination.—The posture was only slightly protective, although there was tenderness in the lumbar region and pain in the lower back and thighs on forced flexion or hyperextension. There was a depression just below the fifth lumbar spinous process and there was also a moderate left dorsolumbar curve. The roentgen ray revealed incomplete ossification of the first sacral arch, a compression fracture of the fourth and fifth lumbar vertebrae, with resulting left curve and distinct posterior dislocation of the fifth lumbar vertebra on the sacrum. Laterally, there was a wide gap between the bodies of the fourth and fifth lumbar vertebrae.

Operation.—April 12, 1921, fusion from the third lumbar vertebra to the sacrum, inclusive, was accomplished. The first sacral arch was found to be incomplete; the fifth was dislocated posteriorly and to the left and rotated sharply to the right. This displacement caused a considerable luxation of the articular processes and allowed a right sided dislocation of the fourth lumbar vertebra. The lamina of the fourth lumbar vertebra on the right was markedly posterior, because of the rotation; on the left, it was fractured and ununited. The lamina of the fifth lumbar vertebra on this side was irregular, also a result of fracture.

Present Condition.—There was immediate complete relief.

CASE 17.—J. C., a laborer, aged 44, big framed and very muscular, at the age of 19 had injured his back by lifting, and it had never been strong since that time. During the year preceding examination here, there had been considerable pain low down, with radiations into the right side and limb. At times, this pain had become so acute that he had had to discontinue his work.

Examination.—The posture was moderately protective, and the lumbar spine was rigid. Motion was almost completely absent, and when elicited it was accompanied by pain. There was tenderness over the fifth and sixth lumbar spinous processes and over the sacro-iliac joints. The roentgen ray revealed a lumbosacral angle of nearly 90 degrees, with anterior displacement of the sixth lumbar vertebra (there were six), and a thinning of the intervertebral spaces above and below it.

Operation.—May 18, 1921, fusion from the fourth lumbar vertebra to the sacrum, inclusive, was accomplished. The spinous processes of the fourth and fifth lumbar vertebrae were tightly wedged together. The entire sixth lumbar vertebra was abnormally mobile and tilted slightly forward. The lumbosacral angle, as viewed from behind, was very acute.

Present Condition.—Relief was complete and the patient is working daily.

CASE 18.—G. de W., a truck driver, aged 30, rather slender, although well-built and of good muscular development, two years previous to his examination

in this dispensary, had been thrown from a motor cycle against a fence. The left leg was injured but apparently the spine was not. Six weeks later, when he commenced work, pain appeared in the lower back; and instead of disappearing, it had become worse. Recently, it had extended down the right limb and had become so severe that he had had to go to bed.

Fig. 11 (Case 18).—Compression and anterior displacement.

Examination.—The posture was protective, with the lumbar region flat and held rigid by muscular spasm. All motion was greatly impaired; and while there was no evidence of cord pressure at the time of examination, he had had some difficulty from that source. The roentgen ray revealed compression fracture of the fifth lumbar and first sacral vertebrae, with one-fourth inch (6.4

mm.) anterior displacement of the former and much decalcification throughout. The third and fourth lumbar vertebrae were apparently normal.

Operation.—May 31, 1921, fusion from the second lumbar vertebra to the sacrum, inclusive, was accomplished. The laminae of the fifth lumbar vertebra were broken loose through the pedicle on the right side and at the base of the spinous process on the left. This part was dislocated posteriorly. The fifth lumbar vertebra itself was thrust forward. The spinous process was flattened from side to side and its long axis was in a lateral position. The fourth vertebra seemed normal; but the laminae of the third were free, as a result of ununited fractures at their bases. The relations were good and the second was in normal condition.

Present Condition.—The patient has experienced complete relief and has resumed his occupation of truck driver.

CASE 19.—F. K., a lead burner, aged 33, stocky, well built and of good muscular development, while working in M—— in April, 1921, when a scaffolding gave way, fell 20 feet (6 meters), amidst numerous rolls of lead. A diagnosis of fractured spine was made, and a plaster jacket applied. Soon after he was sent back to the United States. Severe symptoms of pressure on the cord persisted for more than a month.

Examination.—There was a small, rounded kyphos, with its apex at the first lumbar vertebra. The spinous processes in this region were so close together that they could not be differentiated. There were active pain and spasm on any motion, but especially on extension and right lateral flexion. He had some numbness in the right thigh, and the patellar reflexes were greatly exaggerated. There was a suggestion of ankle clonus. The roentgen ray revealed a compression fracture of the first lumbar vertebra, with a normal intervertebral disk between it and the twelfth dorsal vertebra, and one that was thinned between it and the second lumbar vertebra. The transverse processes of the first, second, third and fourth lumbar vertebrae were fractured on the right side.

Operation.—June 14, 1921, fusion from the eleventh dorsal to the second lumbar vertebra, inclusive, was accomplished. The first lumbar vertebra was displaced backward on the second by impaction between the laminae. Those of the first and twelfth vertebrae were widely separated; and in the midline, the pulsating cord membranes could be seen. The spinous process of the first was directed to the right in its lower aspect. The vertebra itself was very stable.

Present Condition.—There is complete relief, and he has resumed his occupation.

CASE 20.—M. G., woman, bookkeeper, aged 18, heavy set and fat, about three and a half years previously, had fallen five stories, alighting on her feet and buttocks, and fracturing both legs and her spine. She had had constant treatment of all kinds but had never since been free from pain.

Examination.—The posture was severely protective, with marked muscular spasm on manipulation, and limitation of motion in all directions. A small kyphos was present, with its apex at the third lumbar vertebra. The roentgen ray revealed a compression fracture of the second and third lumbar vertebrae, with the third body dislocated slightly to the right side and sharp wedging, anteriorly, of both. The intervertebral disk was partially destroyed. The fourth lumbar vertebra was displaced a short distance to the left side and its spinous process was down next to that of the fifth lumbar vertebra. The spinous processes of the second and third lumbar vertebrae were also impinging.

Operation.—July 12, 1921, fusion from the second lumbar to the fifth lumbar vertebra, inclusive, was accomplished. The spinous processes of the second and third lumbar vertebrae were tightly opposed to one another, even though the third was dislocated downward sufficiently to make contact with the fourth, and the fourth overrode the fifth on the left side for nearly one-fourth inch (6.4 mm.). The second lumbar vertebra was slightly displaced posteriorly on the third, the third was jammed down so far on the fourth that the interlaminal space was almost obliterated. The third was not stable. The fourth was dislocated a short distance to the left side, making possible its peculiar relation to the fifth, which seemed normal. The articular facets were displaced, in keeping with the other parts of the vertebrae.

Present Condition.—The patient is back at work, free from symptoms.

CASE 21.—M. W., a volunteer fireman, aged 29, very large, powerful, and big-boned, a year ago last May was thrown from a fire truck and received what was diagnosed as a fracture of the spine. He was in bed three months, and wore a plaster support for six. The pain in the lower back and down the right thigh, however, had continued. He had been on light duty since September, 1920.

Examination.—The posture was good, except for a slight deviation of the trunk to the left. Flexibility was fairly free, except to the right. Muscular spasm could be elicited only when manipulations were forced. The roentgen ray revealed a compression fracture of the fourth and fifth lumbar vertebrae on the left side, with spinal inclination to the same side and slight posterior displacement of the fifth on the sacrum.

Operation.—Aug. 9, 1921, fusion from the fourth lumbar to the sacrum, inclusive, was accomplished. The spinous processes of the third and fourth lumbar vertebrae were bifurcated in the lower aspect of the tips, and were in contact with the fifth. The fifth lumbar vertebra was dislocated back and down on the sacrum, fully a half inch (12.7 mm.), the articular facets nearly passing one another. The same condition was true of the fourth and the fifth, but only to about half the extent. The relations between the third and fourth were normal except for the spinous processes; so the third vertebra was not included in the fusion.

Present Condition.—The patient is back at work and has no symptoms.

CASE 22.—S. S., a monument worker, aged 18, tall, with fair musculature, when 12 years of age had fallen 10 feet (3 meters), alighting on his buttocks. He was not completely disabled; but since he had been active, there had been a great deal of aching in the lower back and some sharp pain between the shoulders. Also, on one occasion, after an accident, there had been pain in the left hip.

Examination.—The posture was military, with an exaggerated lordosis; but there was prominence of the upper end of the sacrum. The seventh dorsal spinous process was also prominent. There was a wide gap between it and the eighth lumbar vertebra and also between the fourth and fifth lumbar vertebrae. All spinal movements were limited, especially flexion. The lumbar muscles were greatly hypertrophied. The roentgen ray revealed an anterior displacement of the fifth lumbar vertebra on the sacrum, of nearly three-fourths inch (19 mm.). Its relation to the fourth lumbar vertebra seemed normal, although there was thinning and collapse of the bodies of both this vertebra and of the first sacral vertebra. No abnormality of the seventh or eighth dorsal vertebra could be seen.

Operation.—Aug. 31, 1921, fusion from the third lumbar vertebra to the sacrum, inclusive, was accomplished. Fully three-fourths inch (19 mm.) anterior displacement of the fifth lumbar vertebra on the sacrum was found. The neural arch of this vertebra was loose through ununited fractures in the pedicles on either side. The laminae of the fourth lumbar vertebra almost came into contact with the anterior and upper portions of those of the first sacral, although the fourth was tilted down in such a way as to direct them nearly straight back. The position was not stable, but no ununited fracture could be demonstrated. The articular facets of the third vertebra had slid half way past those of the fourth lumbar vertebra, while those of the fifth and first sacral vertebrae were almost completely absorbed. The relations between the second and third were normal.

Present Condition.—The patient is now in school and the symptoms are relieved.

CONCLUSIONS

It is evident from the study of these cases that:

1. Many fracture-dislocations of the spine are not recognized.

2. They occur with greatest frequency in the lumbar spine; and the fifth lumbar vertebra is the one most often injured.

3. Those which take place in childhood may not cause symptoms until adult life, when the completed ossification of the vertebrae destroys their capacity for accommodation to altered shape and position.

4. The symptoms are caused by the mobility of these altered joints and ununited fractures. Elimination of motion is essential to complete and permanent relief.

5. Fusion of the articulating bones is a means to that end. It has been accomplished by the operation herein described, with complete relief in every case.

6. The safety and completeness of the exposure made in this dissection would seem to justify its use as a means of diagnosis in exceptional cases of patients seriously disabled, when every other means has failed, such as Cases 16, 18 and 22.

CARCINOMA OF THE LUNG: A STUDY OF ITS INCIDENCE, PATHOLOGY AND RELATIVE IMPORTANCE

WITH A REPORT OF THIRTEEN CASES STUDIED AT NECROPSY *

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The increasing incidence of carcinoma of the lungs is attracting the attention of many observers. Since the time it was first recognized by Bayle,[1] in 1810, who described it as "phtisie cancereuse," one of his six varieties of phthisis, it has almost been a tradition that carcinoma of the lung is an extremely rare disease of negligible clinical importance and that its antemortem diagnosis is practically impossible. Very few textbooks devote more than a paragraph to the whole subject. A review of the more recent literature shows that it is time to discard these false concepts. The relatively frequent occurrence of the disease is today making imperative for its recognition a more detailed knowledge of its pathology, symptomatology and differential diagnosis.

Hampeln [2] states that the idea of the rarity and undiagnosability of the primary tumors of the lung has been gradually changed since 1895. Not only is there an absolute increase in the number of cases but there is a threefold relative increase. Undiagnosability simply resolves itself into unfamiliarity with the more or less characteristic signs and symptoms. Packard [3] and Fishberg [4] call attention to the evident increasing frequency. The latter adds that this increase has been noted principally by pathologists when making postmortem examinations. Even Adler,[5] as late as 1912, stated that primary malignant neoplasms of the lung are among the rarest forms of disease.

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1. Bayle: Recherches sur la phtisie pulmonaire, Paris, 1810, cited by Cottin et al., Ann. de méd. **8**:435, 1920.

2. Hampeln: 'Zur Symptomatologie und Diagnose der primären malignen Lungentumoren, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **31**:672, 1919.

3. Packard, M.: Primary Malignant Neoplasms of the Lung, Am. J. Med. Sc. **154**:351 (Sept.) 1917.

4. Fishberg, M., and Steinbach, M.: The Diagnosis of Intrathoracic Neoplasms, Med. Rec. **99**:513 (March 26) 1921.

5. Adler: Primary Malignant Growths of the Lungs and Bronchi, New York, Longmans, Green & Co., 1912.

STATISTICS

A careful review of the literature demonstrates the increasing importance of this disease. Some of the reports are not reliable because cases are reported as primary carcinoma without necropsy or histologic studies. Statistical study, therefore, loses in value on account of the unverified cases. Postmortem studies, of course, are generally reliable. According to Weller,[6] the prerequisites of an "authentic" case are: first, necropsy; second, nature of the lesion, verified by the microscope; third, establishment of the fact that the neoplasm is not secondary. Wolf,[7] in a series of 20,116 necropsies in the Dresden Hospital from 1852 to 1894, found forty-five cases of primary lung carcinoma (0.223 per cent.). Füchs [8] reported 0.065 per cent. in a series of 12,307 necropsies from the Pathological Institute of Munich from 1854 to 1885. Reinhardt,[9] in 1878, reported five cases, or 0.057 per cent., of lung tumors among 8,716 necropsies from the City Hospital of Dresden. Pässler [10] found 870 cases of carcinoma among 9,246 necropsies in the Pathological Institute of Breslau, from 1881 to 1894. Of these, sixteen cases, or 0.183 per cent. of the total, were pulmonary cancers. Rolleston and Trevor [11] gave statistics from St. George's Hospital covering the period from 1890 to 1902. Among 3,983 necropsies, there were six sarcomas and only two carcinomas of the lung (0.05 per cent.). They state that primary malignant disease of the lung is very rare and most difficult to diagnose and that sarcomas are more frequent than carcinomas. Von Wiczskowski [12] reports 126 cases among 58,497 necropsies (0.21 per cent.). Briese [13] gives a very careful classification of the necropsy findings in 12,971 cases at the Pathologic and Hygienic Institute of Chemnitz, from 1898 to 1916. Among 1,287 cases of carcinoma encountered in this series, 60, or 0.46 per cent. of the total number of necropsies, were primary tumors of the lung. In a list giving the twenty-four principal organs that were the primary seat of carcinoma, the stomach comes first, with 458 cases; the uterus second,

6. Weller, C. V.: Primary Carcinoma of the Larger Bronchi, Arch. Int. Med. **11**:314 (March) 1913.

7. Wolf, K.: Der Primäre Lungenkrebs, Fortschr. d. Med. **13**:725, 1895.

8. Füchs: Beiträge zur Kenntniss der primären Geschwülstbildungen in der Lunge. Diss. München, 1886.

9. Reinhardt: Der Primäre Lungenkrebs, Arch. f. Heilkunde **19**:369, 1878.

10. Pässler: Ueber das Primäre Carcinom der Lunge, Virchows Arch. f. path. Anat. **145**:191, 1896.

11. Rolleston, H. D., and Trevor, R. S.: A Case of Primary Sarcoma of the Lung Simulating Empyema, Brit. M. J. **1**:361, 1903.

12. Von Wiczskowski: Ueber der Primären Lungenkrebs, Wien. klin. Wchnschr. **26**:1067, 1913.

13. Briese: Zur Kenntniss des Primären Lungenkarzinoms mit statistischen Angaben, Frankfurt. Ztschr. f. Path. **23**:48, 1920.

with 187 cases; the lungs and bronchi sixth, with 60 cases; the breast seventh, with 40 cases, and the pancreas tenth, with 24 cases. I give this series to show how early in the list the pulmonary tumors come. It is of interest that the lung tumors come even before those of the breast. A probable explanation for this fact is that patients with operable carcinoma, such as that in the breast, are most likely to die outside of hospitals, from recurrence or metastasis. Oerstrom [14] gives the percentage as 0.31 in 10,272 necropsies at the Charité Pathological Institute in Berlin from 1900 to 1907. Cottin [15] reports twenty-nine cases encountered in the Cantonal Hospital in Geneva during the years 1900 to 1920. Unfortunately, the total number of necropsies is not given. Symmers [16] reports five cases encountered at the Pathological Laboratory of Bellevue Hospital from 1907 to July, 1919; while from July, 1919, to December, 1920, eight cases were encountered Fishberg [4] reports thirty-three cases from the Montefiore Hospital in New York City during the past five years.

In a series of 4,362 necropsies performed in the Department of Pathology of the University of Minnesota from 1899 to June, 1921, there are recorded thirteen cases of primary carcinoma of the lung (0.29 per cent.). From 1899 to 1911, there is not a single case of carcinoma of the lung recorded in a series of 1,333 necropsies. From 1912 to 1918, inclusive, a period of seven years, there are recorded four cases in a series of 2,026 necropsies, or 0.2 per cent. From January, 1919, to June, 1921, a period of two and one-half years, there were performed 1,003 necropsies; and in this series, nine cases of primary pulmonary carcinoma were found. This makes 0.9 per cent. for this series, giving the highest figure recorded in the literature. Of course, one cannot draw any conclusions from a series so small. Nevertheless, it is of extreme interest to find the figures up to 1918 corresponding very closely to those found in the literature, but that in the period from 1919 to the present time the figure rises abruptly to about four times the average incidence as revealed by large statistics. Kaufmann [17] gives 1.76 per cent. as the frequency of pulmonary carcinoma in relation to carcinomas in general. Since all forms of carcinoma comprise about 10 per cent. of all cases studied at necropsy, Kaufmann's percentage for pulmonary tumors would be less than 0.2 per cent. Ewing [18] places the percentage even lower, approaching more nearly

14. Oerstrom, cited by Edlavitch, B. M.: J. A. M. A. **59**:181 (July 20) 1912.

15. Cottin, Cramer et Saloz: Du Diagnostic de Cancer primitif du Poumon, Ann. de méd. **8**:435, 1920.

16. Symmers, cited by Fishberg and Steinbach: Med. Rec. **99**:513 (March 26) 1921.

17. Kaufmann: Spezielle pathologische Anatomie, Ed. 6, 1911, **1**:310, 1911.

18. Ewing, James: Neoplastic Diseases, Philadelphia, W. B. Saunders Company, 1919, p. 785.

0.1 per cent. The apparent increase in the number of primary lung tumors encountered by the authors above mentioned is: Reinhardt, 1878, 0.057 per cent.; Füchs, 1885, 0.065 per cent.; Pässler, 1894, 0.083 per cent.; Wolf, 1894, 0.223 per cent.; Oerstrom, 1907, 0.31 per cent.; Briese, 1916, 0.46 per cent., and our series, 1919-1921, 0.9 per cent.

ETIOLOGY

The etiology of pulmonary cancer offers the same difficulties of solution as any other type of cancer. Trauma plays perhaps an even lesser rôle that in neoplasms elsewhere, since the lungs are so well protected by a bony cage; but Ewing believes that it has figured prominently in the history of many cases. Race and heredity are apparently unimportant factors. There is a definite relation to sex, the proportion being given as three in the male to one in the female (Adler,[5] Briese,[13] Kaufmann,[17] and Ewing [18]). The greatest incidence is in the sixth decade (about 30 per cent.); and more than 75 per cent. of the cases occur between the ages of 40 and 70. In Briese's series, the youngest patient was 26. Adler cites six cases occurring between the ages of 10 and 20 and Ewing tells of one case in a girl, 7 years old. In our series, 92 per cent. of the cases occurred between the ages of 40 and 70—the youngest patient being 42 and the oldest 72 years.

Perhaps the chief etiologic factors are inflammatory conditions, and of these, tuberculosis is the most important. This is contrary to Rokitansky's old dictum that carcinoma and tuberculosis are incompatible—that tuberculosis practically precludes cancer. Many series of cases in the literature have proved that carcinoma is not infrequently found associated with tuberculosis, developing especially in the scars and walls of tuberculous cavities. The explanation for Rokitansky's statement probably lies in the fact that tuberculosis is a disease of early adult life while carcinoma is a disease of late adult life; the two diseases, therefore, having different age incidence. Paterson [19] suggests that persons possessing an inherited tendency to tissue proliferation might be resistant to the development of tuberculosis.

Kaufmann states that the tumor develops in the walls of bronchiectatic cavities as well as in those of tuberculosis. The bronchiectasis encountered, however, is more often probably the result, rather than the cause, of the neoplasm; the dilatation arising from partial stenosis and secondary inflammatory changes consequent on the new growth. Several of our cases, especially Cases 6 and 10, show this fact very plainly. The unusual statistics from the cobalt, nickel, and bismuth

19. Paterson: Pulmonary Tuberculosis, in Tice, Frederick: Practice of Medicine, Hagerstown, Md., W. F. Prior Company **2**:475, 1920.

mines of Schneeberg, Silesia, for the period of 1879 to 1884, so often quoted in the literature, are now no longer invoked to prove the relation of chronic irritation to cancer. According to these statistics, among from 600 to 700 men employed, there was a yearly mortality of from 28 to 32, of which 75 per cent. were said to be due to pulmonary cancer. It is now believed that most of the lesions then reported were inflammatory and not neoplastic in origin.

I believe that it is not at all unlikely that another chronic inflammatory process may be responsible for a number of pulmonary cancers encountered during the past few years. It is possible that this might explain the rather striking increase in incidence recently. I have in mind the influenza epidemic of 1918-1919. The rather striking increase in the number of cases in our series during the past two and one-half years (nine cases) over that of the previous eighteen years (four cases) was also the experience of Dr. Symmers of Bellevue Hospital in New York, where from July, 1919, to December, 1920, during a period of a year and a half, they encountered eight cases, while during the previous twelve and a half years they had encountered only five cases. In discussing this subject with pathologists from other hospitals, I found that the same impression of an increase in incidence since 1918 seems to obtain. It is, therefore, not far fetched to assume that there may be a causal relation between the residual pulmonary lesions from the influenza epidemic and the present apparent increase in lung carcinomas.

PATHOLOGY

Carcinomas of the lung vary greatly in the gross and microscopic appearances. Some authors try to differentiate between the bronchial and parenchymal carcinomas in their classifications but this distinction is now being discarded. Grossly the tumors may be classified in three types: (1) nodular; (2) diffuse or lobar; (3) infiltrating. The third type is the most common and the second type the least common of these tumors. Most of our thirteen cases belong to the third group. There was not a single case encountered of the second, or diffuse, type. As the name implies, the nodular form is a circumscribed tumor which on section is grayish white or yellowish in color and occasionally shows areas of necrosis and small cavity formation (Fig. 1). The second, or diffuse, type sometimes resembles lobar pneumonia, involving one or several lobes. This type is best illustrated by the case reported by Briese. A man, 49 years old, developed a sudden attack of weakness, dyspnea, slight fever and rapid emaciation. There was marked expectoration but few physical signs. Death occurred within nine weeks after the onset. At necropsy both lungs were found to be equally consolidated and enlarged, the right one weighing 2,360 gm.

and the left one 2,750 gm. There was little crepitation, and the tissues of both lungs sank in water. The cut surface was grayish white; the septums appeared anthracotic and a glairy mucus escaped from the bronchi and parenchyma. The bronchial tree was not infiltrated and there were no metastases except into the prevertebral and peribronchial lymph nodes. Microscopically, the tissue showed the alveolar structure well retained and the principal changes were in the lining epithelium. In place of the very flat alveolar cells, there were single layers of high columnar, closely packed, nonciliated cells. The cytoplasm of these cells stained deeply and many of them showed vacuoles. Some of the large alveoli contained papillary projections. Some areas showed low columnar, cubical or flat cells. Indeed, all gradations from the normal to the high columnar type of cell could be traced out. Most of the alveolar spaces were filled with hyaline or granular masses of mucus and débris. The metastases into the lymph nodes showed the same glandular structure as that of a papillary adenocarcinoma.

A case similar to the one described above is that described by Gordon.[20] A woman, 51 years old, was sick four months, with cough, dyspnea, tachycardia, profuse perspiration and progressive anemia. Physical examination revealed consolidation of the right lung suggesting pneumonia. At necropsy, the entire right lung, except the lower portion, was found to be solid, grayish in color, suggesting the gray hepatization of lobar pneumonia. Microscopically, the alveolar structure was well preserved. The general appearance was the same as that described in the previous case. Another case of this type is reported by Ravenna [21] in a man, 45 years old, who presented consolidation of the right lower lobe. Studies at necropsy revealed changes similar to the preceding. Ravenna believes that this tumor originated in the bronchial epithelium and not in the alveolar epithelium. He quotes Marchiafava [22] and Malassez [23] to support his contention.

The infiltrating variety generally starts from one of the larger bronchi and infiltrates the surrounding lung tissue; sometimes the tumor follows closely along the bronchial ramifications.

The size of the tumors varies. Occasionally, they are so small that only the metastases produce the symptoms. As to location, most

20. Gordon, A. K.: Primary Diffuse Alveolar Carcinoma of the Lung, Lancet **2**:501 (Sept. 4) 1920.

21. Ravenna: Contribution à l'étude du cancer primitif du poumon, Arch. de Méd. exper. et d'anat. Path. **21**:87, 1909.

22. Marchiafava: Di un cancro primitiva del polmone a cellule cilindriche con reproduzione vel cervello e nell osso frontale, Riv. de clin., Bologna **4**: 150, 1873.

23. Malassez: Examen histologique d'un cas de cancer encéphaloïde du poumon, Arch. de physiol. norm. et path. **2**:3[illegible]3, 1876.

authors agree that the right lung is more often involved than the left and that the upper lobe is more frequently affected than the lower. Hampeln, in a large series of cases, found the upper lobe involved about three times as often as the lower.

HISTOGENESIS

The histology of the lung presents three types of epithelial elements which may give rise to tumors: (1) bronchial epithelium; (2) bronchial mucous glands, and (3) alveolar epithelium. The histogenesis of most of the tumors encountered is very difficult to determine except perhaps in very early stages. The difficulty is due to the fact that the morphology of neoplastic cells is modified by inflammatory processes associated with the new growth and that the lung tissue by its very nature is especially susceptible to the development of extensive inflammatory reactions. Besides, the three types of epithelial cells just mentioned are very closely related morphologically; the secretory cells of the mucous glands and the pavement cells lining the alveoli are only slightly modified columnar cells which line the bronchi. It is far-fetched, therefore, to conclude, as some authors do, that the squamous-cell carcinomas have their origin in the alveolar epithelium merely because they happen to be flat squamous cells. Similarly, some authors trace the origin of certain tumors to the mucous glands simply because there is an abundant mucoid secretion in the tissue; but the presence of intracellular or intra-acinar mucus is no evidence of the origin of the tumor from the glands, to the exclusion of its origin from bronchial epithelial cells, since the latter also secrete mucus.[6] Thus, we find that the criteria for the origin of some of the tumors described in the literature are erroneous.

Most authors believe that the majority of these tumors arise from the bronchial epithelium and that only a very few arise from the parenchymal or alveolar epithelium. The cases of Briese, Gordon and probably Ravenna, cited above, most likely belong to the latter group; but these cases are so rare that, as Adler well points out, a primary carcinoma of the lung is a bronchial carcinoma. Pässler claims that no definite case has as yet been shown to have originated from the alveoli. Kaufmann believes, on the other hand, that these tumors arise principally from the mucous glands.

Histologically, lung cancers may be classified into several groups:

1. Cylindric cell carcinoma: (*a*) adenocarcinoma; (*b*) carcinoma simplex; (*c*) scirrhous carcinoma; (*d*) alveolar carcinoma; (*e*) medullary carcinoma, and (*f*) colloid or gelatinous carcinoma.
2. Squamous-cell carcinoma (cancroid).
3. Mixed type.

The cylindric cell carcinomas are the most common of the lung tumors. These may be subdivided into types, depending on the arrangement and grouping of the cells. Of these, the adenocarcinoma is the one most often encountered. Figure 7 represents a typical example of adenocarcinoma. There are typical glandlike structures, lined by one or several layers of cylindric epithelium. In cases of diffuse (alveolar) carcinoma, large papillary invaginations are often present, suggesting the papillary type of adenocarcinoma. Many of the lining cells show vacuoles containing mucoid secretion. In a few cases reported, the alveoli are filled with quantities of mucinous material. When this material is very abundant, both the gross and microscopic pictures suggest colloid or gelatinous carcinoma. Both Aschoff [24] and Kaufmann [17] refer to this type. Some authors are of the opinion that this abundance of mucus demonstrates the origin of this type of tumor from the mucous glands. As has been mentioned, this is not a safe basis for such conclusion. Another group of tumors shows arrangements strongly resembling the bronchial mucous glands (Fig. 3). In these glandlike structures, the individual cells have very distinct cell outlines and cell walls. This fact I believe to be of importance in tracing their histogenesis from the bronchial glands.

Carcinoma Simplex.—This tumor arises from either the bronchial epithelium or from the mucous glands. It shows irregular, solid nests or cords of undifferentiated epithelial cells surrounded by a connective tissue stroma.

Scirrhous Carcinoma.—Some tumors are slow growing and present enormous amounts of connective tissue proliferation with relatively few tumor cells. It is quite likely that this type of tumor originates most frequently from the mucous glands. Figure 11 illustrates this type. Langhans [25] reports a scirrhous type of carcinoma in which he traced an unbroken series of hyperplastic glands into infiltrating cords of tumor cells. His case is very similar to our Case 13. Some areas show an overgrowth of glands which break up and become dislocated in the dense connective tissue stroma, as cords and strands of cells. Langhans believes that the deeper acini are the ones to become first involved.

Alveolar Carcinoma.—Large solid masses of pleomorphic cells occupy spaces resembling lung alveoli. Often the connective tissue septums between the tumor cells are the remains of the alveolar walls, a fact demonstrable by the use of elastic tissue stains which show the presence of elastic fibers.

Medullary Carcinoma.—A small group of cases present microscopic pictures which make it difficult at times to differentiate between

24. Aschoff: Pathologische Anatomie, Ed. 3 **2**:333, 1913.

25. Langhans: Primärer Krebs der Trachea und Bronchien, Virchows Arch. f. Path. Anat. **53**:470, 1871.

carcinoma and sarcoma. The cells are often compact, small, pleomorphic and have very little cytoplasm. Figure 4 illustrates such a case. It is quite likely that a number of tumors reported as sarcomas in the literature belong to this type. Ewing believes that of the ninety cases of sarcoma reported by Adler only a minority present sufficient evidence to justify their separation from the diffuse carcinomas. From the description, the case reported by Blumgarten [26] corresponds more to a carcinoma than to a sarcoma, though he reported it with the latter diagnosis. He describes closely packed cells, collected into islands or columns or forming the lining of the alveolar spaces. Rolleston and Trevor state that the primary tumor of the lung is generally in the nature of sarcoma, a conclusion directly opposed to that of most observers. Aschoff, for example, states that of the primary lung tumors sarcoma is extremely rare. It is very likely that the English authors are confused in the identification of these tumors.

Colloid or Gelatinous Carcinoma.—This type of tumor I have already described under the adenocarcinomas. No case of this type was encountered in our series.

Squamous-Cell Carcinoma.—This is a very interesting type of tumor, especially from the standpoint of its histogenesis. It has attracted the attention of many observers. Statistics vary as to its frequency. In our series we had one cornifying and one noncornifying type of cancroid. In classifying eighty-five cases of carcinoma from the literature, Henrici [27] found twelve cases of acanthomas, of which only four were cornifying. Wolf [28] found eight acanthomas among fifteen bronchial carcinomas. According to the statistics of Watsuji,[29] 32.2 per cent. of all pulmonary carcinomas are of the pavement cell variety. This is certainly not borne out by statistics in general. The statistics of Knieriem [30] relative to his findings on the proportions of pulmonary cancers appear to coincide more accurately with the general statistics on this subject. He reported, in 1909, that in Leipzig during nine years there were seven acanthomas in a total of seventy-five cases of cancer of the lung—an incidence of about 10 per cent.

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26. Blumgarten: Primary Malignant Tumor of the Lung, M. Clinics N. Am. **2**:1145, 1919.

27. Henrici: Primary Cancer of the Lung, J. M. Research **21**:395, 1912.

28. Wolf, cited by Ewing, James: Neoplastic Diseases, Philadelphia, W. B. Saunders Company, 1919, p. 789.

29. Watsuji: Ztschr. f. Krebsforsch. **1**:445 (cited by Adler: Footnote 5).

30. Knieriem: Ueber ein primäres Lungenkarzinom, Verhandl. d. deutsch. path. Gesellsch. 1909, p. 407.

The origin of this type of tumor is still under discussion. Schottelius [31] believes that it has its origin in the lymphatic endothelial cells. This view has, of course, been discarded. Another view is that it originates in the basement epithelial cells of the alveoli. Edlavitch [32] reports a case of acanthoma in which he says the tumor cells have a striking resemblance to the squamous epithelium normally lining the air spaces; and he, therefore, concludes that the tumor arose from the alveolar epithelium. I have already pointed out the fallacy of such a conclusion. Another theory is that these tumors arise from epithelial rests. This is a possibility; but the more accepted theory is that of cellular metaplasia. The consensus of opinion now is that the acanthomas nearly always arise through epithelial metaplasia in the bronchi. Ernst [33] believes that the tumor may develop in an area of preexisting squamous-cell metaplasia. He cites the case of Seigert [34] in which a benign papilloma with epithelial pearls was found in the trachea at the bifurcation. He believes that such a benign tumor may undergo malignant change. Haythorn,[35] working in the Magie Laboratory of the Mercy Hospital, Pittsburgh, found areas of squamous-cell metaplasia in the epithelium of the bronchi in three cases of pneumonia. He believes that the squamous epithelium replaced the columnar epithelial cells after the latter disappeared through the inflammatory process. Davis and LeCount,[36] in their case of squamous-cell carcinoma of the main left bronchus, found that the mucosa of the trachea from 1 cm. above the bifurcation, extending well into both primary bronchi, resembled skin. In this case, also, the metaplasia apparently appeared first.

As has already been mentioned, a condition often associated with acanthoma is tuberculosis. Kaufmann, Aschoff and others believe that most cases of this type of tumor originate in the scars and fibrotic walls of tuberculous cavities. Askanazy [37] has shown that squamous epithelium may result from irritation in the respiratory tube. He found patches of this type of epithelium replacing the columnar ciliated epithelial cells of the trachea and bronchi in thirty-eight out of ninety

31. Schottelius: Ein Fall von Primären Lungenkrebs., Diss. Würzburg, 1874.

32. Edlavitch, B. M.: Primary Carcinoma of the Lung, J. A. M. A. **59**: 181 (July 20) 1912.

33. Ernst: Ein verhorenden Plattenepithelkrebs des Bronchus: Metaplasie oder Aberration, Beitr. z. path. Anat. u. z. allg. Path. **20**:155, 1896.

34. Seigert: Ueber primäre Geschwülste der unteren Luftwege, Virchows Arch. f. path. Anat. **129**:413, 1892.

35. Haythorn, cited by Henrici: J. M. Research **21**:395, 1912.

36. Davis and Le Count: Report of Two Cases of Primary Bronchus Carcinoma, Tr. Chicago Path. Soc. **7**:129, 1908.

37. Askanazy, M.: Ueber die Veränderungen der grossen Luftwege besonders ihre Epithel-mätaplasie bei der Influenza, Cor.-Bl. f. schweiz. Aerzte **49**: 80 (Jan. 18) 1919.

cases in which the patients had died in the influenza epidemic of 1918. The multiple layers of stratified epithelium extended into the ducts of some of the glands. He believes that such epithelial metaplasia may predispose to tumor formation. Ernst calls attention to the fact that cornifying squamous epithelium is not infrequently encountered in ozena, chronic endometritis, tuberculosis of the trachea, ichthyosis of the tongue, etc. Squamous epithelial cells are sometimes found also in the gallbladder and kidney pelvis as a result of irritation from calculi. Figure 10 shows an excellent example of a cornifying squamous-cell carcinoma and Figure 2 shows a noncornifying one.

The possibility of these tumors arising from metaplasia of alveolar epithelial cells as well as of bronchial epithelium cannot be denied.

Mixed Type.—A few tumors have been encountered in which there are several types of cells and structures. Meyenburg[38] has found such a tumor in the lower part of the trachea. The tumor showed areas of typical basal-cell carcinoma with areas of cornification on the surface and areas containing cylindric cells and ciliated columnar cells in other parts. No tumor of this type was encountered in our series.

METASTASES

The metastases from lung carcinomas are frequent and numerous. According to Adler, the principal metastases in his collection of 374 cases were to these organs: (1) lymph nodes, 117; (2) liver, 103; (3) lungs, 66; (4) kidneys, 58; (5) suprarenals, 38; (6) brain, 28 (dura mater, 10), and (7) bones (vertebrae, 5).

Briese in his series of sixty cases found metastases absent in only four cases. Of the twenty-one organs and tissues listed in the order of frequency, the principal ones involved were: (1) regional lymph nodes, 43; (2) liver, 25; (3) pleura, 17; (4) kidney, 17; (7) lungs, 11; (8) brain, 11; (9) bones, 9; (12) ovary, 7; (13) suprarenals, 6, and (17) dura, 3.

These statistics are fairly representative of the findings of most observers. The relative frequency of kidney, brain, thyroid and suprarenal metastases is worthy of note. The sparseness of cases reported with bone metastases may be due to the fact that, at routine postmortem examinations, the involvement of bones is often overlooked. Often in only those cases in which definite symptoms had resulted from bone lesions are the bones examined. As previously mentioned, the metastasis sometimes presents the principal and only symptoms. Numerous cases may be found in the literature in which only the necropsy revealed the true primary lesion when the clinical diagnosis

38. Meyenburg: Ueber eine Basalzellengeschwulst der Trachea mit teilweiser Differenzierung zu Pflaster- und Zylinder bzw. Flimmerepithel, Centralbl. f. allg. Path. u. path. Anat. **30**:577, 1920.

of cerebral hemorrhage, brain tumor or abdominal tumor had been made. Boecker [39] reported a case of primary carcinoma of the right lung in which the clinical diagnosis had been cerebral apoplexy. The necropsy, however, revealed the true lesion. Brain metastases are so frequent that one should always keep this fact in mind in cases in which brain symptoms develop in conjunction with evidences of indefinite, progressive, pathologic conditions of the chest. In one of our cases (Case 7) the brain symptoms predominated; while in another case (Case 13) the only findings elicited clinically were those of lumbar Pott's disease.

SYMPTOMATOLOGY

The symptoms of lung tumors may be so variable as to cause great confusion in diagnosis. The reason for this is quite obvious: The entire respiratory tract is subject to such a large variety of inflammatory processes which produce symptoms and findings that fairly blend into one another. Besides, lesions in the mediastinum also produce secondary effects on the lungs. In addition to these processes, there is still a third complication which causes great confusion in symptoms, that of inflammatory processes, such as bronchiectasis, which so frequently complicate pulmonary tumors. The symptoms, therefore, are at times inflammatory rather than neoplastic in origin. Case 10 illustrates this fact very well, when even the roentgen-ray findings varied so much from time to time that some of the staff, including the roentgenologist, thought the process must be an inflammatory one.

Although cancer of the lung presents no pathognomonic symptoms, there are groups of symptoms that are fairly common in this disease. I shall discuss the most important ones.

1. *Cough.*—This is a frequent and early symptom. It is often very annoying. At first the cough is dry but later it may become rasping and productive.

2. *Pain.*—This is commonly present. At times it consists only of a sense of discomfort or oppression in the chest. In some cases, there are unilateral intercostal neuralgias or pain in one shoulder or arm These have a slow onset and not the acute onset of ordinary neuralgias. The pain may be due to the cancer cells infiltrating the nerve bundles. Figures 6 and 13 show how extensive this infiltration frequently becomes.

3. *Dyspnea.*—This is a late symptom. Early there is a sense of oppression in the chest which gradually may develop into a mild and later into a severe dyspnea. At times it may go on to orthopnea.

39. Boecker: Zur Kenntniss der primären Lungenkarzinom, Virchows Arch. f. path. Anat. **202**:38, 1910.

4. *Weakness.*—In some cases, a general sense of weakness begins quite early.

5. *Cachexia.*—Usually, the cachexia is not marked except in the late stages. The loss of weight as a rule is only mild or moderate.

6. *Fever.*—This symptom is not infrequent because of the inflammatory complications so often present. Some patients even have chills and night sweats.

Of the physical findings, only a few need be mentioned. One of these is flatness of the chest when an effusion is present. A prominent finding is "cornage," a condition which is dependent on partial obstruction to a bronchus. The persistence of this sign when other findings were disappearing was the basis of insisting on the diagnosis of carcinoma in one case of our series (Case 10).

The term "cornage" was first used by a Frenchman, Behier,[40] and designates a peculiar type of tubular breathing elicited by auscultation, which is caused by the narrowing of the bronchus by compression. Cornage, together with bloody sputum, is very significant.

LABORATORY FINDINGS

Examination of the blood furnishes nothing characteristic. The sputum is frequently tenacious and may be blood streaked. A sanguinous sputum is fairly common during some stage of the disease. Occasionally, the so-called "current jelly" sputum may be obtained. Some patients have recurrent periods of expectoration of large quantities of mucopurulent or purulent material. This is generally due to bronchiectasis which develops as a result of stenosis of some part of the bronchial tree. A history of a thin mucosanguinous sputum extending over a period of weeks or months without much fever, chills or night sweats is very suggestive of a bronchial ulceration from a neoplastic growth. Of course, chronic passive congestion of the lungs must be borne in mind. Some authors have described large clear fatty cells in the sputum but these are not at all constant. According to Fishberg, a pleural exudate is present in 50 per cent. of the cases. This exudate is yellowish at first but later may become sanguinous or purulent. However, the fluid is not characteristic. The large cells containing vacuoles sometimes present in the fluid, which are considered of some importance by a few observers, are probably nothing more than degenerating desquamated endothelial cells.

DIAGNOSIS

Some cases of uncomplicated cancer should offer no difficulty in diagnosis. When there is a history of gradual insidious onset, per-

40. Behier: Hôp. de la Petie, Gaz. d. hôp. **45**:177, 1867, cited by Cottin: Ann. de méd. **8**:435, 1920.

sistent thin mucosanguinous expectoration, slight or no increase in temperature, thoracic pain, evidence of pulmonary induration on physical examination associated perhaps with "cornage," a definite asymmetry of the chest together with subclavian or axillary adenopathy and, in addition, perhaps some roentgen-ray findings—such a group of symptoms and findings obviously enough point to a definite diagnosis, but, unfortunately, only a few of the cases present so classical a picture. Since no symptoms or physical findings per se are entirely pathognomonic (that which may be decisive in one case may be negligible in another), it is very important that a detailed history be taken and a complete and thorough physical examination be made. All facts obtainable in the case should be carefully collected and correlated. The sputum should be examined both for the absence of tubercle bacilli and for positive cytologic findings. Whenever indicated, paracentesis should be performed and the exudate studied. If enlarged lymph nodes are present, especially when these nodes appear in unusual locations on the chest wall, biopsies should be resorted to. Cottin and his co-workers found adenopathy in about 66 per cent. of their cases. Most of the recent observers state that the clinical diagnosis is made principally on the history, course, symptoms and physical signs; the laboratory procedures, such as roentgen-ray, sputum and chest fluid examinations, though useful and necessary, are more for confirmation than for actual diagnosis.[41] Fishberg and Steinbach state that they failed, only once during the past five years, to make a correct diagnosis in their series of thirty-three cases, while only four cases of this same series were diagnosed correctly before admission. The preliminary diagnoses in this series indicate some of the conditions that are to be considered in differential diagnosis. They are tuberculosis (13 cases), pleurisy with effusion or empyema (7 cases), chronic pneumonia (2 cases), neurologic (1 case), lung abscess (2 cases), cardiac disease (2 cases) and carcinoma of the lung (4 cases). To this list may be added mediastinal tumor (mediastinal [Hodgkin's] sarcoma), aortic aneurysm and mediastinal and encysted abscesses. Fishberg points out that there are two symptoms in carcinoma which are rarely seen in early tuberculosis: (1) pain in the chest, and (2) dyspnea. He says:

"Nearly all patients with malignant growths in the chest cough and expectorate sputum. It is important to think of a pulmonary neoplasm when a patient in the cancer age, showing no symptoms of cardiac, renal or arterial disease, begins to cough and is short-winded. In patients who have passed middle age, pain in the chest, with or without a pleural effusion, is suggestive. Patients with enlarged tuber-

41. Fishberg, M., and Steinbach, M.: Footnote 4; Von Wiczskowski: Footnote 12.

culous glands in the neck hardly ever have signs of active disease in the lungs, while when the glands are malignant we find signs of extensive changes in the lungs."

I would recommend the reader to refer to Fishberg's original article for a concise detailed study of the diagnosis of intrathoracic neoplasms.

Another author emphasizes the possibility of properly diagnosing lung tumors clinically by making very exact physical examinations. Sehrt [42] states that during twelve years of practice he diagnosed correctly during life nine cases out of a total of ten cases which he encountered.

Many authors have found the roentgenogram either of negative value or at times even misleading. This is contrary to the statement of McMahon and Carman [43] that in most instances the roentgenologic findings in primary carcinoma are pathognomonic of the disease and may be the first to suggest the exact nature of the pulmonary lesion. I have observed in our series of cases, as well as in the reports from the literature, that this is not the usual experience. It is readily seen that the concomitant inflammatory reactions and bronchiectases may give conflicting shadows, a condition well illustrated in Case 10 of our series. Two other means of diagnosis are mentioned here, simply because they are sometimes invoked for aid. These are bronchoscopy and pulmonary biopsy. Both are so difficult to perform that their use is not to be encouraged at the present time. When, however, the tumor infiltrates and finally perforates the chest wall so as to present subcutaneous nodules, then a biopsy is indicated.

COMPLICATIONS

Bronchiectasis is a very common and important complication. Pulmonary hemorrhages may occur from erosions; but these are usually small. Very rarely, there are erosions of the large branches of the pulmonary artery or vein with resultant fatal hemorrhages. Stillman [44] reports a case which presented a marked swelling of the neck. Necropsy showed that this was due to thrombosis of the inferior vena cava resulting from a tumor mass around the right bronchus.

PROGNOSIS

The prognosis at the present time is hopeless. The course varies from several weeks to four or five years, the majority of cases running a course of about one or one and a half years.

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42. Sehrt, cited by Wiczskowski: Wien. klin. Wchnschr. **26**:1067, 1913.

43. McMahon and Carman: The Roentgenologic Diagnosis of Primary Carcinoma of the Lung, Am. J. M. Sc. **155**:34 (Jan.) 1918.

44. Stillman: Carcinoma of the Bronchus with Thrombosis of the Superior Vena Cava, Proc. New York Path. Soc. **20**:66, 1920.

TREATMENT

The difficulties of treatment in this disease are enhanced by the location, the lesion being enclosed in a bony cage, the chest cavity. Surgical interference is not readily applied to this location. Besides, most of the tumors are located at the hilum of the lung, a location in close proximity to the cardiac space and also directly in the region of the pulmonary vessels. In a few cases, excision of the affected tissue has been attempted; but the results are disappointing. Roentgen-ray and radium therapy have thus far also proved of little or no value. The treatment, therefore, resolves itself entirely into the treatment of symptoms.

CARCINOMA IN ANIMALS

Primary carcinoma of the lungs in animals is not infrequent. Slye [45] reports the occurrence of cancer of the lung in about 1 per cent. in a series of 6,000 mice. Tyzzer [46] also reported large spontaneous lung tumors in mice. Seigert [47] reported a case of a large primary cylindric-cell carcinoma in the lower lobe of the lung of a dog. Histologically, he could trace the origin and gradual transition of the tumor from the superficial epithelium of the bronchus.

The thirteen cases in our series are taken from the records of the Department of Pathology, University of Minnesota, covering a period of about twenty-one years. Only concise abstracts of the histories and necropsy protocols will be given. The first case of the series occurred in 1912. Cases 7 and 10 were under my personal observation at the University Hospital and will be given in somewhat greater detail.

REPORT OF CASES

CASE 1 (Necropsy 12-114 [48]).—Mrs. I. T., aged 52, became sick in March, 1912. In July, she developed a severe cough with profuse expectoration. She lost considerable weight; a right-sided effusion developed, and she died Aug. 31, 1921. No clinical diagnosis was stated in the records.

The necropsy was performed by Dr. H. E. Robertson. The body was poorly nourished. The right pleural cavity contained about 2 liters of brownish-red fluid. The middle and lower lobes of the right lung were atelectatic and solid. The upper lobe was normal. There was a large tumor mass surrounding the bronchi near the hilum. This had a soft necrotic reddish-brown center about 2.5 by 4 cm. in extent, with a grayish periphery of infiltrating tumor about 1.5 cm. in thickness (Fig. 1). Small tumor nodules were scattered through the

45. Slye, Holmes and Wells: Tumors of the Lungs in Mice, J. M. Research **25**:417, 1914.

46. Tyzzer: A Series of Spontaneous Tumors in Mice, Fifth Report, Cancer Commission Harvard University, 1909, p. 153.

47. Seigert: Zur Histogenesis der primären Lungenkrebs, Virchows Arch. f. path. Anat. **134**:287, 1893.

48. The first two figures of the necropsy number represent the year in which the necropsy was performed.

Fig. 1.—Right lung from Case 1, showing the centrally located, large tumorous mass with the necrotic center and cavity formation. Its spread is peripherally, from around the secondary bronchi.

Photomicrographs were made by Mr. Henry W. Morris, medical photographer, Department of Pathology, University of Minnesota.

parenchyma. There was a tumor nodule in the left lung near the hilum. The peribronchial lymph nodes were enlarged and infiltrated. Microscopically, sections of the lung showed tumorous areas of glandlike structures lined with irregular columnar epithelial cells. The diagnosis was adenocarcinoma of the right lung with metastases into the lung parenchyma and peribronchial lymph nodes.

Case 2 (Necropsy 13-63).—J. F. O'N., man, aged 50, in November, 1912, developed a troublesome cough. Later he suffered severe pain, like neuritis, in the right sacroiliac joint. He was sent to a hospital for an operation but none was performed. The cough was persistent and occasionally the sputum was blood-streaked. He died suddenly, April 19, 1913.

Necropsy was performed by Dr. H. E. Robertson. The body was well nourished. There was a palpable mass above the clavicle. The left pleural cavity contained about 200 c.c. of fluid. There were numerous grayish-white

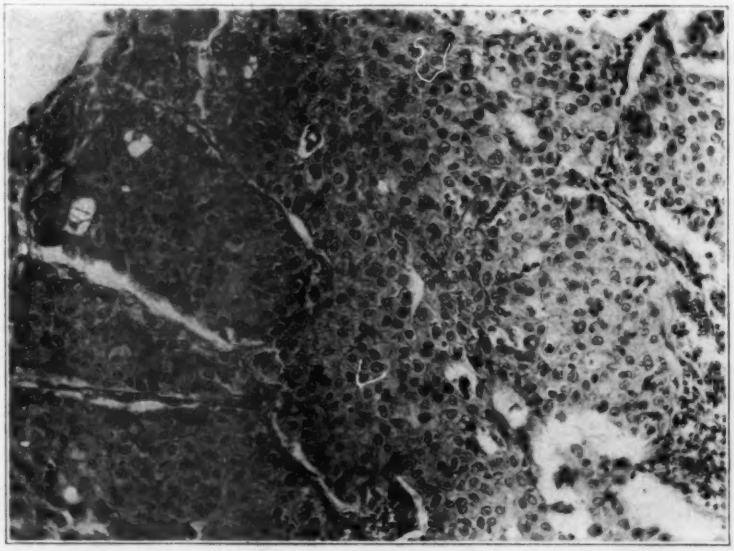

Fig. 2.—Section from tumor of lung from Case 2, showing the closely packed epithelial cells and the narrow strands of connective tissue stroma, probably remnants of the alveolar walls. There is no keratinization but intercellular bridges are visible. This is a good example of a nonkeratinizing squamous-cell carcinoma.

nodules, 2 to 10 mm. in diameter, in the posterior portion of the left lung. Near the base, there was a necrotic, hemorrhagic tumor mass the size of a hen's egg. On section, a mucoid substance came from the cut surface. The tracheal, bronchial, periaortic and inguinal lymph nodes were markedly enlarged. The right pelvic floor was infiltrated. Microscopically, the lung alveoli were partially filled with pleomorphic cells. The nuclei were vesicular. The cytoplasm was deeply staining and contained numerous vacuoles. The alveolar walls were well retained. Numerous mitotic figures were present. Some areas on section showed marked fibrosis; and there was an infiltration of round cells

and small clumps and cords of tumor cells. In some of the clumps of tumor cells, intercellular bridges might be seen; but there was no cornification or epithelial pearl formation (Fig. 2). The diagnosis was nonkeratinizing squamous-cell carcinoma of the left lung, with metastases into the lymph nodes and pelvic floor.

CASE 3 (Necropsy 14-133).—H. K., man, aged 52, first felt ill in March, 1914. He developed pain in the stomach, anorexia and vomiting after each meal. He gradually lost in weight and strength. He was admitted to a hospital, May 5, 1914, where he died, July 12, 1914, no clinical diagnosis having been made.

Necropsy, performed by the author, revealed a poorly nourished body. The left pleural cavity was completely obliterated by strong adhesions. There were a few adhesions at the right apex. There were small grayish nodules at the right apex and around the bronchi of the middle and lower lobes. There was a large tumorous mass near the hilum which infiltrated the parenchyma around the bronchi. There was an increased amount of cerebrospinal fluid in the subarachnoid space and in the ventricles. A tumor mass, 3 cm. in diameter, involved the basal nuclei in the floor of the right ventricle. There was another tumorous mass, 1 cm. in diameter, in the right lobe of the cerebellum. Microscopic examination of the lung revealed alveolar spaces lined with single or multiple irregular layers of columnar cells. The alveolar walls were thickened. Another section showed marked fibrosis, anthracosis and chronic tuberculosis with tubercle formation, containing giant cells. The diagnosis was adenocarcinoma of the right lung with metastases to the brain.

CASE 4 (Necropsy 17-214).—W. R., man, aged 55, admitted to the University Hospital, June 8, 1917, complaining of pain in the right axilla, shoulder and chest, had always been well until Oct. 2, 1916, when he first noticed pain in the left shoulder, anorexia and beginning weakness. From this he recovered slowly and went back to work. In February, 1917, he noticed a swelling of the face which was present only in the daytime at first, but later became persistent. He developed a severe cough and marked dyspnea. He had considerable expectoration. He had to quit his work, May 5, 1917, because of the severity of the symptoms.

Physical examination revealed hyperresonance and impaired voice transmission over the scapular region on the right side. Some areas showed absence of breath sounds. The superficial veins over the trunk and head stood out prominently. There was edema of the face and hands. The pain gradually extended upward over the thorax. Oct. 3, 1917, general anasarca developed. The fingers became clubbed and the finger nails became shaped like watch-crystals. He developed marked dyspnea and Cheyne-Stokes' respiration. He died, Oct. 18, 1917.

The laboratory examinations of the sputum and blood and the phenolsulphonephthalein test and Wassermann reaction were negative.

Necropsy, performed by the author, revealed a poorly nourished body. There was edema of the face, neck, left forearm and hand. Both pleural cavities were obliterated by strong adhesions. The lower portion of the right upper lobe was hard and nodular and adhered strongly to the chest wall by means of infiltrated tumor masses. The lower two thirds of the left upper lobe was also firm and nodular, presenting a tumor mass around the bronchus, 8 by 3 cm. The outer portion of this mass was necrotic and showed intense anthracosis. The color was bluish black. A tumor mass, 3.5 cm. in diameter, was present in the right

lower lobe. This infiltrated the pleura and the diaphragm. The superior vena cava, together with the lower portion of the subclavian and jugular veins, was plugged with tumor masses mixed with thrombus. The anterolateral portions of the first, second, third and fourth ribs on the right side were destroyed by infiltrating tumor masses.

Microscopic sections of the lung showed marked fibrosis with hyalinized connective tissue through which were scattered nests and cords of closely packed pleomorphic epithelial cells. Irregular areas of necrosis were scattered throughout. The diagnosis was carcinoma simplex of the left lung with metastases into the lung, peribronchial lymph nodes, pleura, ribs and superior vena cava.

This case closely resembles the one reported by Stillman.[4]

Case 5 (Necropsy 19-35).—J. P., woman, aged 58, was admitted to the University Hospital, Dec. 22, 1918, complaining of weakness, shortness of breath, excessive perspiration and severe attacks of coughing. She was sent in with the diagnosis of lumbago, bronchitis and possible bronchopneumonia. Her illness began in June, 1918, with weakness and a sense of continuous exhaustion. About that time she fell from a ladder and struck her chest with a plank. Later she caught cold and developed a cough. She was confined to her bed because of weakness. Examination demonstrated a shallow jerky type of breathing with diminished resonance and vocal fremitus over the left apex. The breath sounds were of a high pitched bronchovesicular type over this area. The sputum showed no tubercle bacilli and no red blood cells. The blood examination, blood chemistry and blood pressure were practically normal. The roentgenogram showed a dense shadow at the left base with infiltration of both apexes which was thought to be an old tuberculous process. The temperature rarely rose above 99.6 F. The pulse ranged between 100 and 130. Respirations ranged from 20 to 32. The patient was discharged, Jan. 26, 1919, with a diagnosis of carcinoma of the lung.

She was admitted to another hospital, Feb. 17, 1919, complaining of dyspnea, cough, blood-streaked sputum, soreness of the chest, hoarseness, occasional attacks of vomiting, marked weakness and progressive loss of weight. A diagnosis of pulmonary tuberculosis was made. Physical examination at this time showed marked emaciation with retraction, asymmetry and relative dulness of the left chest. Sputum was negative for tubercle bacilli on five occasions. Several days before her death, March 10, 1919, she developed fluid in the left chest.

Necropsy, performed by Dr. E. T. Bell, revealed a poorly nourished body. There was edema of the feet. Each pleural cavity contained about 2,000 c.c. of clear fluid with fibrinous flakes. There were a few adhesions at both apexes. The left lower lobe was hard and nodular. The cut surface showed closely approximated irregular whitish tumor masses. There were small tumor nodules in the right lower lobe, in the liver, suprarenals and kidneys.

Microscopic sections of the tumor showed irregular glandlike structures lined by very sharply defined large cuboidal and columnar epithelial cells. Numerous desquamated epithelial cells with abundant mucoid material were present in most of the lumina (Fig. 3). The type of cells suggested glandular epithelium. A diagnosis was made of adenocarcinoma of left lung (probably originating from bronchial mucous glands) with metastases into lung, peribronchial and mediastinal lymph nodes, liver, suprarenals and kidneys.

Case 6 (Necropsy 20-316).—H. O., male, aged 42, was admitted to the surgical service of the University Hospital in January, 1920, with a diagnosis of empyema or malignancy. The illness dated back to August, 1919, when the

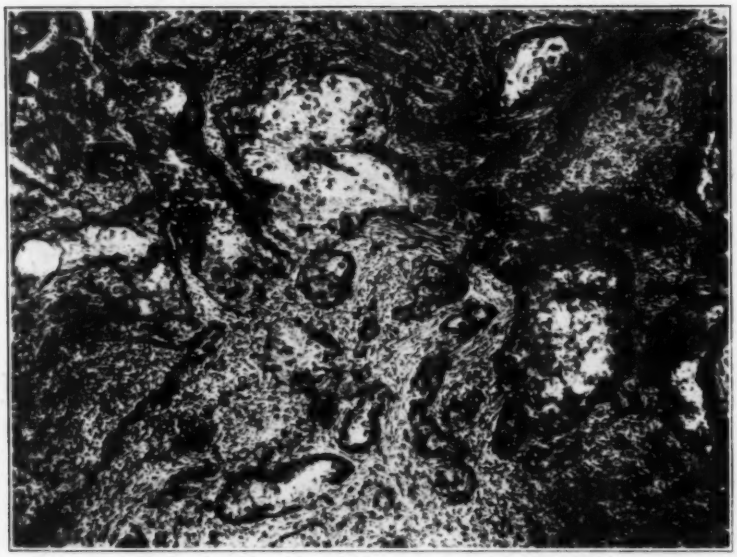

Fig. 3. — Section of tumor from Case 5, showing the atypical glandlike structures containing a mucoid secretion and desquamated epithelial cells. The individual cells have sharply defined cell walls and lightly staining cytoplasm. This is an adenocarcinoma, probably originating from the mucous glands.

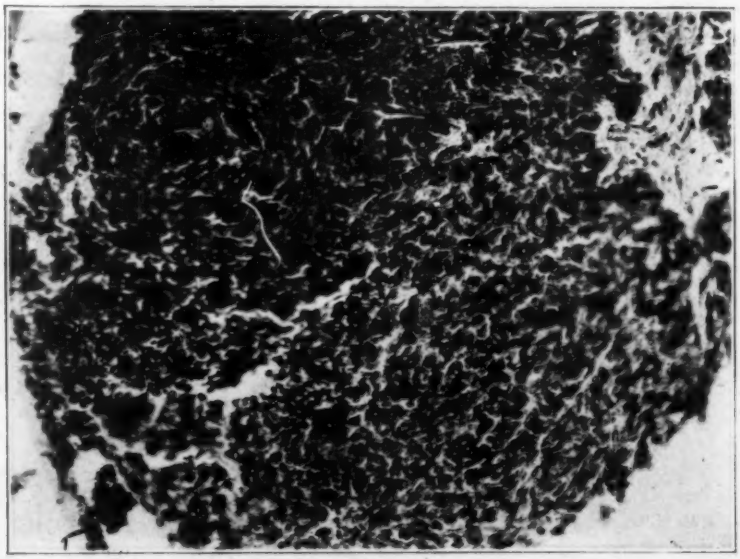

Fig. 4.—Section of tumor from Case 6, showing the closely packed spindle-shaped cells which strongly suggest sarcoma. It is only by careful study of sections from the different organs that the epithelial nature of this tumor can be identified. This tumor may be classed among the medullary carcinomas.

patient became sick suddenly, with chills, severe cough, fever, pain in the left side of the chest, loss of appetite and weakness. He was in bed about a month. The cough was productive, slimy, and on one occasion the sputum was bloody. The diagnosis at the time was bronchopneumonia. Since then he had had occasional attacks of shooting pains over the left chest with shortness of breath and severe coughing spells. The patient thought he had been gradually improving. Physical examination at the hospital revealed a marked lagging of the left side of the chest with a friction rub, anteriorly and posteriorly. There was dulness and hyperresonance over the left apex and left base. The breath sounds were markedly diminished at the apex and absent at the base. The chest was aspirated for fluid but none was obtained. The blood showed a slight leukocytosis. The urine was negative. The roentgenogram showed a dense shadow in the left side of the chest with the heart displaced to the left. The diagnosis was marked thickening of the pleura, probably an unrecognized empyema. He was discharged from the hospital with this diagnosis

He was admitted to the Minneapolis General Hospital, Aug. 8, 1920. He then complained of hoarseness and bloody sputum of about a month's duration. For several months, he had felt that food stuck in his throat. He lost 35 pounds (15.9 kg.) in weight. The roentgenogram at that time showed an opacity of the mediastinum extending through most of the left upper lobe of the lung. The diagnosis was mediastinal sarcoma. He died, Aug. 13, 1920.

Necropsy, performed by Dr. T. H. Sweetser, revealed edema of the feet and ankles. The left lung was very firmly adherent to the chest wall. The pericardium contained a seropurulent exudate. The mediastinum was involved in a tumor mass made up of large white lymph nodes which were matted together. A tumor mass infiltrated the parenchyma around the upper and main branches of the left bronchus. The bronchus was ulcerated in this region. Small masses were scattered through the parenchyma. Numerous large bronchiectatic cavities were scattered throughout the lung. The spleen was enlarged and on section showed a tumor mass, 8.5 by 6.5 cm. There was a tumor, 3 by 4 cm., in the tail of the pancreas.

Microscopically, sections of the spleen showed masses of closely packed, irregular, spindle-shaped tumor cells, containing very little cytoplasm. Many mitotic figures were present. This section suggested sarcoma very strongly (Fig. 4). The peripheral sinuses of a lymph node contained tumor cells, singly and in clumps, having vesicular nuclei and abundant cytoplasm. These cells were fairly characteristic epithelial cells. Section through the bronchus showed the epithelial type of tumor cells infiltrating the stroma. The diagnosis was medullary carcinoma of the left lung with metastases into the mediastinal lymph nodes, pleura, spleen and pancreas. This type of tumor offered great difficulties in differentiating carcinoma from sarcoma. Some observers might include this case under the sarcomas; but careful study of sections from the different organs convinces me that it is an epithelial type of tumor.

Case 7 (Necropsy 20-363).—L. H., man, aged 46, was admitted to the University Hospital on the neurologic service, Sept. 16, 1920. He was sent in with a diagnosis of left-sided hemiplegia and left-sided pleurisy. The past history was unimportant. He had always been a strong, healthy, hard working farmer. In the fall of 1919, he developed a slight cough and later noticed that the sputum was blood tinged on a number of occasions. His physician told him that the blood probably came from the tonsils. In February, 1920, he developed severe pain in the right thigh and leg, which was treated as sciatica.

Fig. 5.—Trachea and lung from Case 7, showing the complete occlusion of the left bronchus by the tumor mass, both in the bronchus itself below the tracheal bifurcation and in the cross-section of the lung at the hilum, transversely to the bronchus. The pulmonary artery and vein are seen adjacent to the tumor mass which contains the occluded main bronchus. The lung parenchyma is completely collapsed.

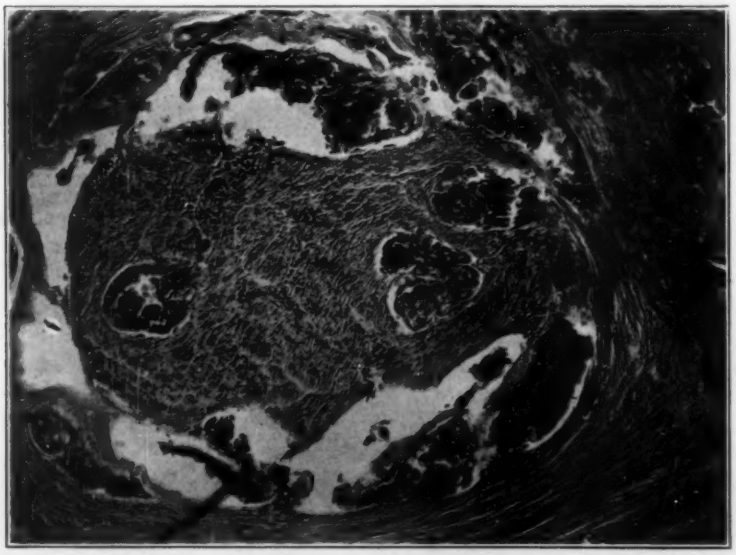

Fig. 6.—Cross-section of a nerve bundle from Case 7, showing invasion of the tumor cells. Compare with Figure 13.

June 2, he suddenly developed a peculiar attack during which everything seemed to turn black before his eyes. He stiffened out, but did not lose consciousness. The next day he went back to work as usual, feeling entirely well. About six weeks later, he first noticed a weakness in his left arm. This increased progressively. Later he noticed a weakness also in his left leg. During the first week of September, he was in bed because of a fever, ranging between 101 and 103 F. From then on he began losing in weight and in strength quite rapidly. He lost 30 pounds (13.5 kg.) in about two months.

Physical examination demonstrated asymmetry of the left chest which was depressed and revealed practically no movement in respiration. It was flat on percussion and the dulness fused with that of the cardiac dulness. The breath sounds were absent. The right cardiac border was displaced to the left to about the midsternal line. There was a flaccid paralysis of the left arm and paresis of the left leg. There was definite atrophy of the muscles of the left chest, shoulder, forearm and hand with a marked loss of tone.

The patient showed marked mental depression, crying a great deal. Examination of the eye grounds revealed a papillo-edema of the third degree but he complained of no headache. Temperature, pulse and respiration were normal. September 22, paracentesis of the left chest was performed; 500 c.c. of clear yellowish fluid was obtained. The fluid contained 430 cells, nearly all lymphocytes, per cubic millimeter. No tubercle bacilli were found. September 27, 250 c.c. of similar fluid was obtained. The blood showed a leukocytosis ranging from 12,000 to 15,000.

A roentgenogram report stated that there was a massive shadow which involved the entire left chest. The heart was displaced to the left. The diagnosis was either a thickened pleura or old empyema or a primary new growth of the pleura.

The patient became gradually weaker and died, Oct. 1, 1920. Because of the history of bloody sputum and the marked asymmetry of the chest, together with the signs of obstruction of the bronchus and the development of hemiplegia associated with signs of intracranial pressure, a clinical diagnosis of primary tumor of the lung with metastasis to the brain was made.

Necropsy, performed by the author, revealed a markedly emaciated body. There was fulness of the neck above the clavicle. The left pleural cavity appeared to be filled by the pericardial sac, which was enormously distended. The left lung was entirely collapsed and retracted, being about the size of an orange. About 800 c.c. of amber fluid was present in this cavity. The pericardial sac contained about 1,500 c.c. of thin dark colored bloody fluid. The pericardium showed no evidences of ruptured blood vessels to explain the blood. The pericardial reflections at the bases of the large vessels were greatly thickened and injected. The posterior third of the right lung showed edema and congestion. The left lung was small and hard. It measured 15 by 12 by 6.5 cm. and weighed 400 gm. It did not crepitate and it sank in water. Numerous small nodules were scattered over the pleura and over the adjacent pericardium. On section of the lung, the lower lobe looked like a triangular fibrous mass. Numerous yellowish nodules were scattered over the cut surface, particularly along the course of the main bronchus. The upper lobe appeared less fibrous and was dark red. Small tumor nodules were also scattered through this lobe. Examination at the hilum revealed an apparent absence of the bronchus. Careful examination of the left bronchus showed that it was completely occluded by a tumor from a point 2.5 cm. below the tracheal bifurcation (Fig. 5). The right

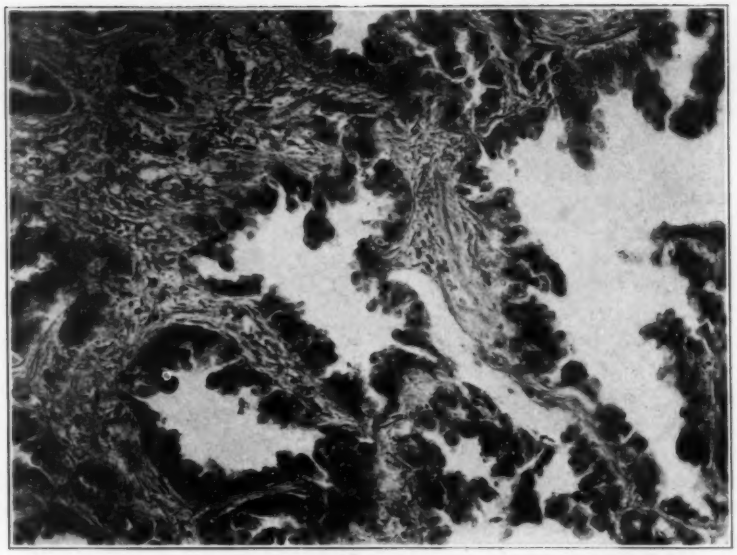

Fig. 7.—Section of tumor in the lung from Case 8. This is a typical example of the common type of adenocarcinoma. The pleomorphic type of columnar cells lining the spaces and the small papillary projections may be noted.

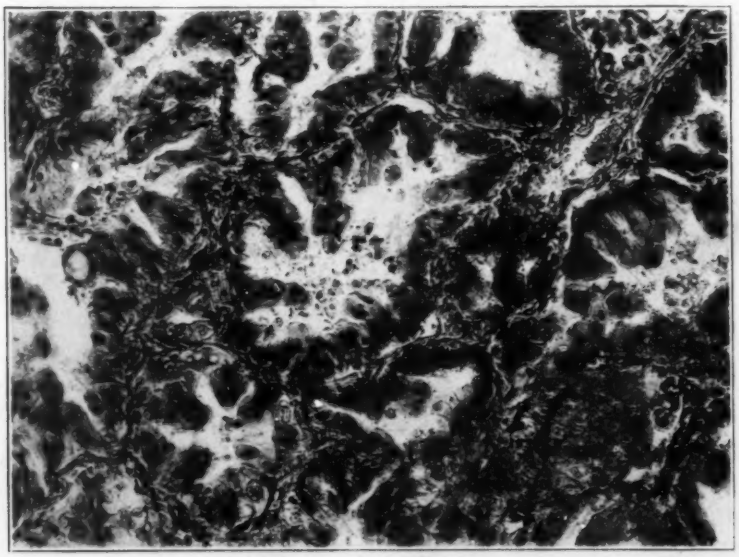

Fig. 8.—Section of lung from Case 9, showing the closely approximated glandlike spaces lined by lightly staining high columnar cells, possessing very sharp cell outlines. The clear spaces within the cells contain a mucoid secretion and some of these look like goblet cells. This is an adenocarcinoma, arising probably from the mucous glands.

suprarenal was large and infiltrated by tumor. In the brain, a tumor mass, 7.5 by 6.5 by 2.5 cm. was found involving the right frontoparietal region. It appeared to involve the dura mater primarily with extension into the cerebral cortex.

Microscopically, the lung showed atypical glandlike structures lined by high columnar cells. The cartilage of the bronchus was invaded by tumor masses. There was marked invasion of the nerve bundles with tumor cells (Fig. 6). The mucosa of the lumen was greatly thickened by papillary projections of infiltrated tumor cells. The heart showed the epicardium infiltrated with small nests of tumor cells and lymphocytes; numerous hemorrhages were scattered throughout the epicardium (this explained the extensive hemopericardium). The adventitia of the pulmonary artery was infiltrated with adenomatous structures and solid masses of tumor cells containing calcified corpora amylacea. These corpora appeared to arise from clumps of necrotic tumor cells. In the brain, the invading tumor mass showed atypical glandlike structures; many cells contained clear spaces filled with mucoid material. The diagnosis was adenocarcinoma of the left bronchus with metastases to the lungs, pericardium, suprarenal and brain.

Case 8 (Necropsy 20-396).—G. E., man, aged 72, was admitted to a hospital, Oct. 17, 1920, complaining of anorexia, vertigo, headache, dimness of vision and some deafness. These symptoms began about Aug. 1, 1920. Up to that time he had been entirely well. Since then he had been losing in weight. Physical examination showed the left pupil to be irregular; and there was a slow nystagmus. There was decreased tactile fremitus and breath sounds over the left lung, posteriorly. There was a firm mass, 8 by 4 cm., in the abdomen just to the left of the umbilicus. The blood showed 13,800 leukocytes with a normal differential count. A clinical diagnosis of pulmonary tuberculosis with abdominal tumor was made. Death occurred, Oct. 30, 1920.

Necropsy, performed by Dr. E. T. Bell, revealed a poorly nourished body. There was edema of the dependent parts. There were numerous strong adhesions at the right apex. Scattered through both lungs were tumor nodules, from 5 to 10 mm. in diameter. There was a large tumor, 5 cm. in diameter, in the middle of the posterior border of the right lung. The cut surface of this was grayish white in color and firm. The bronchi and bronchioles were apparently uninvolved. The liver showed a number of tumor nodules. There was a small nodule in the thyroid.

Microscopically, lung sections showed pleomorphic, cuboidal and columnar cells, lining glandlike spaces (Fig. 7). Many lymphatics were plugged with clumps of tumor cells. Sections of the thyroid and liver showed areas of atypical glandlike structures. The diagnosis was adenocarcinoma of the right lung, with metastases into lungs, liver and thyroid.

Case 9 (Necropsy 21-8).—J. E., woman, aged 61, was admitted to a hospital, Dec. 1, 1920, complaining of sharp, stabbing pain in the chest, emphasized by inspiration. She had been operated on for goiter, November 11, and ten days later had noticed pain in the left side of the chest which was not relieved by strapping. She developed some dyspnea.

Physical examination revealed asymmetry of the chest, with lagging, impaired resonance and a bronchovesicular type of breathing over the left side of the chest. There were tenderness and rigidity of the left upper abdomen. The laboratory examinations were negative except that the urine showed a trace

of albumin and a few waxy and hyaline casts with leukocytes and red blood cells. The roentgenogram showed a definite shadow involving the left hilum. The patient died Jan. 3, 1921. No clinical diagnosis was stated in the record.

Necropsy, performed by Drs. J. S. McCartney and E. T. Bell, revealed a poorly nourished body. Both lungs contained numerous miliary nodules. There was a large firm tumor mass involving the left upper lobe, which was continuous with a smaller mass which involved and almost obstructed the upper left bronchus. The lymph nodes along the left sternocleidomastoid muscle were enlarged. There was a small tumor nodule in the thyroid. The pleura over the seventh, eighth and ninth ribs on the left and the eighth and ninth ribs on the right was elevated, thickened and boggy, being invaded by tumor tissue which had also involved and destroyed the contiguous ribs.

Microscopically, the lung showed irregular glandlike structures lined by irregular layers of high columnar cells (Fig. 8). The cell outlines were very sharp and distinct. Many of the cells contained vacuoles filled with mucoid secretion. Some suggested goblet cells. The tumor tissue resembled very closely secreting grandular tissue. Sections of the tumor masses in the thyroid, lymph nodes, pleura and striated muscles showed solid clumps and cords of epithelial cells separated by masses of connective tissue. There were no adenomatous structures. These areas resembled more a nonkeratinizing squamous-cell carcinoma. The diagnosis was atypical adenocarcinoma, probably arising from mucous glands, with metastases into the lungs, lymph nodes, thyroid, ribs and muscles.

Case 10 (Necropsy 21-147).—S. M., man, aged 48, was admitted to the University Hospital, Jan. 5, 1921, complaining of a severe cough, especially on lying down, dyspnea, weakness and pain in the right chest. He had lost 50 pounds (22.7 kg.) in weight during the past two years, his average weight having been 165 pounds (75 kg.) while now it was 115 pounds (52.2 kg.). He was sent in with a diagnosis of aneurysm(?), bronchiectasis(?), asthma(?). His past history was unimportant up to two years previously, when he began tiring easily and losing in weight. About the middle of the summer of 1920, he developed daily nosebleeds and a cough which soon became associated with severe pain in the right upper chest. About October 1, the nosebleeds stopped and he began to spit up small quantities of blood. Since that time he had been coughing and spitting blood daily. About November 25, he had to quit his work.

The patient was markedly emaciated. The upper right chest lagged and there was increased fremitus with relative dulness over the right apex, both anteriorly and posteriorly. The breath sounds were tubular and bronchovesicular in type over this area and also in the right axilla. The inspiratory tone was rough and grating, followed by a very prolonged expiratory note—cornage. The tone was much like that due to a partial compression of the trachea. During the first few weeks in the hospital, the patient spat up thin tenacious, bloody sputum. Later this became purulent in character. Because of the history of bloody sputum, the pain in the chest, the dulness and tubular breathing (cornage), the absence of crepitant râles and the usual absence of temperature, a tentative diagnosis of primary carcinoma of the lung was made.

The roentgenologic studies, January 11, revealed a nonpulsating mass in the mediastinum extending into the right upper chest. The diagnosis was mediastinal tumor or aneurysm, probably the former. February 17, the stereoscopic

roentgenograms showed an old pleurisy at the right base, with the remains of an interlobar pleurisy of the upper and middle lobes on the right side. The diagnosis was fibroid tuberculosis of the right upper lung. The mass previously described was gone and probably represented an atypical pneumonia or some acute glandular involvement which had subsided. March 14, the roentgenologic diagnosis was bilateral pulmonary tuberculosis, more marked on the right side.

The physical signs, February 15, showed a marked improvement, but the cornage remained. March 10, the physical signs reappeared over the upper

Fig. 9.—Right lung from Case 10, showing irregular carcinomatous masses in the hilum surrounding the bronchus. The peripheral portion of the lung is riddled with bronchiectatic cavities containing precipitated thick pus.

right lobe. The cough became more severe and the sputum more abundant. March 20, the patient developed a severe chill, and within a few hours the temperature rose from normal to 103 F., with a pulse of 130 and respirations, 38. He complained of great pain and discomfort in the chest. Examination at this time revealed a marked lagging of the right chest with evidences of consolidation and persistence of the tubular breathing.

Examination of about twenty specimens of sputum disclosed absence of tubercle bacilli. The urine was negative. The blood was generally negative but on one or two occasions showed a leukocytosis of from 24,000 to 28,000, of which 90 per cent. were polymorphonuclears. The hemoglobin dropped somewhat during the stay in the hospital. The blood Wassermann reaction was negative. Blood chemistry was negative.

His weight dropped to 100 pounds (45.4 kg.) on February 2, a loss of about 15 pounds (6.8 kg.) from the time of admission. This rose again to 115 pounds (52.3 kg.) on March 6, at the time when there was an apparent general improvement in his condition. He died, March 25, 1921.

Necropsy, performed by Dr. H. S. Diehl, revealed a poorly nourished body. The right pleural cavity was obliterated by firm fibrous adhesions. There was a small quantity of thin purulent exudate between the adhesions. The pericardial cavity contained 100 c.c. of thick purulent exudate. The left lung was normal.

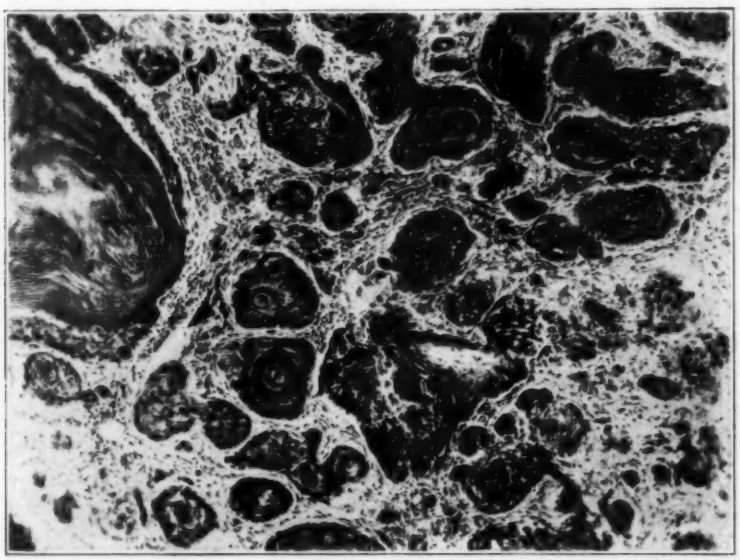

Fig. 10.—Section of suprarenal from Case 10, showing clearly the nests of epithelial cells of different sizes containing concentric cornified epithelial centers. The epithelial pearls in this case are unusually typical. All the metastases as well as the primary lesion are true to the type of squamous-cell carcinoma.

The right lung was solid except in the inferior part of the lower lobe. Section through the upper and middle lobes showed numerous bronchiectatic cavities, from 5 mm. to 1.5 cm. in diameter (Fig. 9). These cavities were filled with thick pus. There was a tumor mass in the right bronchus, bulging into and markedly obstructing the lumen. Section of this mass showed it to be of a grayish white color and firm. It extended along the bronchus and for a short distance into the surrounding parenchyma of the upper lobe. The lymph nodes at the hilum of the lung were markedly enlarged, filled with whitish

masses. There were several small tumor nodules in the liver. Both suprarenals were somewhat enlarged and firm and infiltrated with tumor masses. There were tumor nodules throughout both kidneys. Small tumor nodules were scattered throughout the thyroid.

Microscopically, the lung showed fibrosis with areas of necrosis. Scattered throughout the section were masses of tumor cells composed of squamous epithelium showing cornification with the formation of epithelial pearls. Some of the veins appeared to be thrombosed and organized and through them were scattered cords of tumor cells. Section of the suprarenal showed an infiltration of masses of squamous epithelium containing epithelial pearls identical with those found in squamous-cell carcinoma of the skin (Fig. 10). Sections of the liver and thyroid also showed masses of squamous epithelium with epithelial pearls. The diagnosis was squamous-cell carcinoma of the lung arising from the right bronchus with metastases into the peribronchial and mediastinal lymph nodes, liver, suprarenals, kidneys and thyroid.

CASE 11 (Necropsy 21-191).—A. F. H., man, aged 63, in February, 1921, developed malaise and a severe cough. Physical examination was negative. Fluoroscopic examination of the chest demonstrated a mass to the right of the heart which on subsequent examinations showed increase in size, filling up the upper right chest cavity. The cough and dyspnea became progressively worse. He developed a constant severe pain in the right arm, associated with edema. The left pupil was dilated; the right contracted. They did not respond to light or accommodation. The neck became large and the veins appeared large and tortuous. The Wassermann reaction was negative. The sputum was negative. The blood was normal. He developed a rise of temperature and died April 30, 1921.

Necropsy, performed by Dr. J. S. McCartney, revealed a well-nourished body. There was marked edema of the right forearm and hand. The right pleural cavity contained 300 c.c. of fluid. The upper right lobe was adherent to the chest wall by dense fibrous adhesions. The entire upper lobe was hard, nodular and grayish white on section. The tumor mass surrounded the bronchus. The mucosa from a point 3 cm. above the bifurcation downward to 5 mm. into the left bronchus and 3 cm. into the right bronchus appeared raised and roughened but apparently not ulcerated. The tumor infiltrated peripherally. The tumor mass extended around the vessels of the neck and the superior vena cava and filled up the space beneath the arch of the aorta. There was also invasion of the pericardiums and a nodule 1 cm. in diameter projected into the pericardial cavity. Tumor nodules were present in the base of the right lobe. The liver and kidneys contained small tumor masses.

Microscopically, the wall of the trachea was densely infiltrated with pleomorphic tumor cells; the cartilage was not invaded. Lung sections showed irregular masses of tumor cells surrounded by connective tissue stroma. The cells were large, pleomorphic with deeply staining nuclei, and were closely packed together (compare Fig. 4, Case 6). The tumor cells in the kidney appeared the same as in the lung. The diagnosis was medullary carcinoma of the right lung, with metastases into the lower lobe, liver, kidneys and pericardium with extension into the posterior mediastinum.

CASE 12 (Necropsy 21-216).—J. R. McK., man, aged 60, began ailing in the winter of 1920 but had no definite symptoms. In August, 1920, he developed a cold and in one of the coughing spells he suddenly experienced a sharp pain

in the left side of the chest, posteriorly. This was relieved by morphin. The pain recurred in about a month and from then on persisted in spite of opiates. Later, this pain radiated down into the left arm and at times also into the right arm and upward into the neck. He developed cyanosis of the arms, neck and head. For two months he noticed great difficulty in swallowing food and in speaking. He developed marked dyspnea. A diagnosis of mediastinal tumor, probably sarcoma, was made. He died, May 14, 1921.

Necropsy, performed by Drs. J. S. McCartney and H. B. Sweetser, revealed a fairly well nourished body. There was edema of both feet. The mesenteric lymph nodes were large and firm. There was a nodule in the peritoneum over the lower pole of the left kidney. There was a fusiform enlargement of the third and seventh ribs on the right side. The left pleural cavity contained 500 c.c. of slightly turbid fluid. There were dense adhesions at the apex. The right cavity contained a similar amount of fluid. The left upper lobe was nodular. There was occlusion of the main bronchus by a tumor mass which infiltrated the surrounding parenchyma. Smaller masses were scattered throughout other parts of the lung. They were also present over the pleura and over the external surface of the root of the aorta. The lymph nodes at the bifurcation of the trachea were greatly enlarged. The tumor mass surrounded the root of the aorta and the main branches of the arch. The spleen, suprarenals and kidneys contained small tumor nodules. The lymph nodes in the left side of the neck were enlarged and on section showed tumor masses.

Microscopically, sections of the different organs showed atypical gland-like structures lined by cylindric cells. Many of these contained quantities of mucoid material. The cellular outlines were very sharp and distinct. The diagnosis was adenocarcinoma of the left lung, probably originating from the mucous glands, with metastases into the cervical, peribronchial, mediastinal, mesenteric and retroperitoneal lymph nodes, ribs, kidneys, suprarenals, spleen and extension into the mediastinum.

Case 13 (Necropsy 21-239).—C. M. W., man, aged 46, was well until the summer of 1918, when he first noticed a pain in the back while playing golf. This was diagnosed as rheumatism. Then, suddenly, a deformity developed in the back. In February, 1920, he went to take mud-baths. He had pain in both legs and felt very weak. He then went to a chiropractor under whose treatment he became much worse. At Christmas time, 1920, he went to Rochester where a diagnosis of Pott's disease was made. He was admitted to a tuberculosis sanatorium, March 21, 1921, after having had a variable experience with physicians and hospitals. Physical examination demonstrated large lymph nodes in the left inguinal region and a knuckle deformity in the region of the twelfth dorsal vertebra. He had large decubitus ulcers. Examination of the chest revealed nothing abnormal. The diagnosis of Pott's disease was made. April 30, physical examination revealed dulness in the right chest with breath sounds distant at this point. Paracentesis was performed but no fluid was obtained. He died, June 2, 1921.

Necropsy, performed by Dr. J. S. McCartney, revealed a poorly nourished body. There were large decubitus ulcers. There was a caseous nodule in the lower lobe of the left lung, 5 mm. in diameter. There was a definite thickening of the left primary bronchus with invasion of the adjacent portions of the secondary bronchi. There was no definite ulceration. There were large tumor

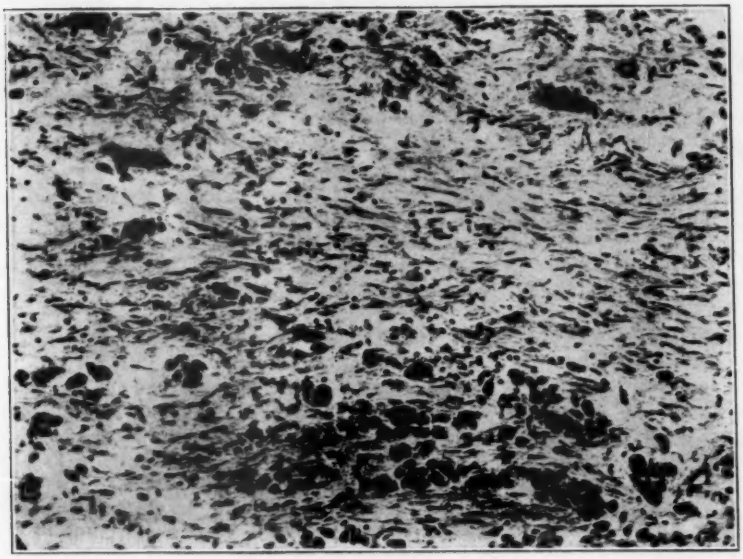

Fig. 11.—Section of lymph node from Case 13, showing clearly the few small nests of epithelial cells scattered through the connective tissue stroma. This is an example of a scirrhous carcinoma.

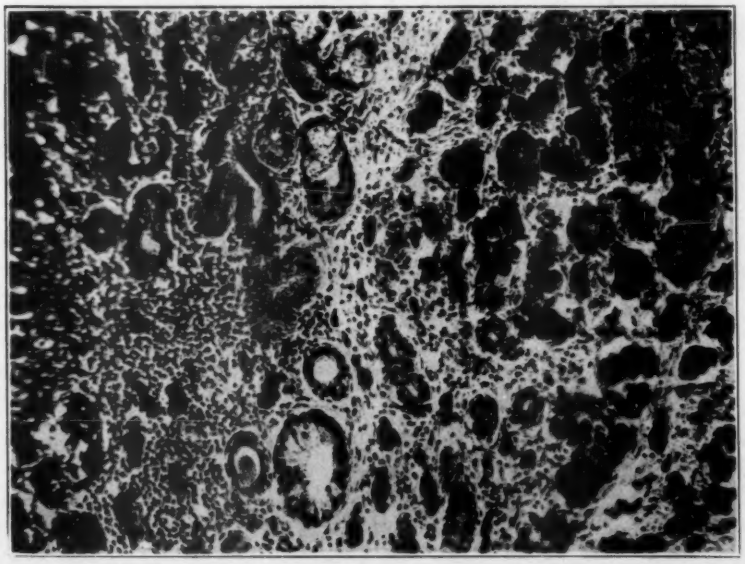

Fig. 12.—Section through wall of bronchus in region of primary nodule from Case 13 (same case as Fig. 11), showing the fairly normal mucous gland ducts and acini next to structures in which there is a breaking away of the epithelial cells into the surrounding stroma, which at the same time assume a deeper cytoplasmic stain. At the margins of the section, frank carcinomatous tissue can be seen. A study of sections from this case convinces me of the origin of this tumor from the mucous glands.

nodules in the right kidney and in the periaortic lymph nodes. There was an irregular tumor mass which invaded the second and third lumbar vertebrae. This extended throughout the bodies into the spinal canal, pressing on the cauda equina. There were tumor masses around the twelfth dorsal and first, second, third and fourth lumbar spinal roots.

Microscopically, sections of the lymph nodes showed dense masses of fibrous connective tissue with very small groups and cords of epithelial tumor cells (Fig. 11). There were a few giant cells of the Langhans' type. Section of the bronchus showed the epithelium intact in most areas. The mucous glands showed transitions from the normal appearance to a marked distortion with breaking through of the epithelial cells into the surrounding stroma (Fig. 12). The retroperitoneal tissue showed a marked infiltration of tumor cells with invasion of nerve bundles (Fig. 13). Sections of the spinal cord showed extensive degeneration, a transverse myelitis. There was a perivascular infiltration with peculiar large pleomorphic cells, possessing abundant bluish

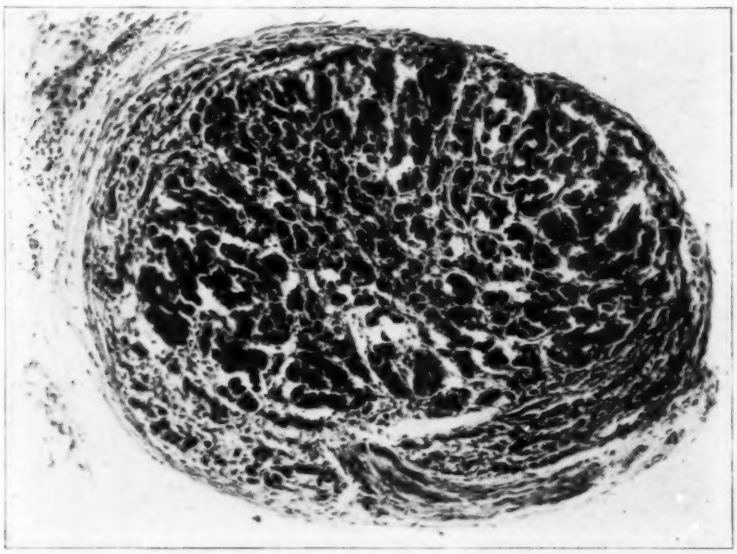

Fig. 13.—Section through a nerve bundle from the retroperitoneal tissue of Case 13. The extensive invasion of the carcinomatous tissue and the almost complete destruction of the nerve fibers may be noted. Compare with Figure 6.

cytoplasm and deep staining nuclei. These cells were also diffusely scattered through the degenerated parts of the cord. The diagnosis was scirrhous carcinoma of the left lung, originating from the mucous glands of the bronchus, with metastases into the lumbar lymph nodes, vertebrae, dura mater and left kidney.

COMMENT

In a brief résumé of this relatively small series of thirteen cases, it will be seen that the findings bear out in a striking manner the observations in the literature as to the characteristics and peculiarities of the disease. As to age, the youngest of the series of patients was

42 and the oldest 72, with an average of about 55 years. Ten were men and three were women. The right lung was primarily involved five times; the left, eight. This is not entirely in accord with the statistics, which give a predominance of right-sided involvement. The shortest duration of symptoms was six weeks and the longest three years, the average about seven months. A severe cough was present in nine cases and bloody sputum in five. Pain in the chest was a prominent symptom in six cases, while one patient (Case 3) complained of pain and distress in the stomach. There was a marked loss of weight in seven cases and there was more or less dyspnea in about 50 per cent. of the series. A pleural effusion was present in six instances and a pericardial effusion in two. In none of these was the fluid at all characteristic except perhaps in Case 10 in which the pericardial fluid was sanguinous and very abundant. Tuberculosis was definitely associated with the disease in only one case and periods of fever in four cases. On five occasions, the chest was grossly asymmetrical. Massive bronchiectasis occurred twice. Metastases were present in every case; and in two instances (Cases 7 and 13), the metastases produced the predominating symptoms. The organs involved together with the frequency of their involvement may be listed thus:

Lungs	10
Lymph nodes	9
Peribronchial and mediastinal	7
Cervical	2
Abdominal	2
Kidney	5
Suprarenal	4
Liver	4
Bones	4
Ribs	3
Vertebrae	1
Thyroid	3
Brain	2
Spleen	2
Superior vena cava	2
Pericardium	2
Pancreas	1

Of the types of carcinoma encountered, adenocarcinoma leads, with seven cases; acanthoma and medullary carcinoma, of each two cases; carcinoma simplex and scirrhous carcinoma, of each one case.

Correct clinical diagnoses were made in only three instances (Cases 5, 7 and 10). In one of these (Case 5), a diagnosis of tuberculosis was made both clinically and by roentgenogram after a diagnosis of pulmonary carcinoma had been made in another hospital at a previous admission. Necropsy proved that the first diagnosis was correct. In Case 8 a clinical diagnosis of pulmonary tuberculosis and abdominal tumor was made. This abdominal tumor proved at necropsy to be nothing more than a deformity of the vertebral column in the lumbar region, which was easily palpable through the thin abdominal

wall. One case was diagnosed as mediastinal sarcoma and another case as Pott's disease. The latter case is of especial interest because the metastases produced the sole and only symptoms and because of the prolonged course of the disease, three years. The roentgenologic studies did not assist in a correct diagnosis in a single case and in several cases they were definitely misleading.

One patient (Case 2) complained of a severe neuritic pain in the right sacro-iliac joint. Similarly, another patient (Case 7) was treated for right-sided sciatica. It is very likely that both patients developed these symptoms from the pressure of tumor metastases on the spinal cord or nerves, though the exact source of the pain was not identified at the postmortem examination.

In Cases 6 and 7, the heart was displaced markedly to the left, toward the affected side. This is sometimes the result of adhesions pulling the pericardium; but in carcinoma of the lung, the mechanism of this displacement is quite different. The occlusion of the bronchus by the tumor mass prevents the air entering into the distal lung parenchyma and, with the gradual absorption of the gases resulting in a negative pressure on the affected side, the relatively increased pressure on the nonaffected side gradually pushes the mediastinum over. In Case 10, the heart was pushed over entirely into the left pleural cavity because the left lung had contracted to the size of an orange and only a small quantity of fluid was present to compensate for the loss of lung mass. The development of this negative pressure on the affected side also explains the asymmetrical chest, with the definite lagging and immobility. The cardiac displacement and the asymmetry of the chest are very important findings for diagnosis.

In Case 6, the patient was apparently improving at one stage of his illness after he had been sick in bed for one month with what was thought to be bronchopneumonia. This probably was an attack due to extensive bronchiectasis, resulting from the bronchial stenosis. Another patient (Case 10) had several similar attacks though of shorter duration. In both of these cases, extensive bronchiectases were found at the postmortem examinations. The very confusing roentgenologic reports in Case 10 can readily be explained by a filling up and emptying of the many diffuse bronchiectatic cavities (Fig. 9).

Cases 6 and 10 had periods of remission with general improvement of the conditions of the patient, subjectively as well as objectively. There is a common impression that loss of weight and weakness are progressive in cancer. This is not always true, however, as the patient in Case 10 regained 15 pounds (6.8 kg.) in weight, as well as his strength, at one time while in the hospital. This fact led some to believe that the patient was on the road to recovery and that the tentative diagnosis of carcinoma of the lung was erroneous.

Case 13 is of interest from the standpoint of diagnosis. Some of the best men in the country had failed to diagnose the case correctly. The completely negative chest findings were very misleading, as they precluded the possibility of locating the primary lesion in the lungs. The metastases to the vertebrae must have occurred rather early, while the primary tumor itself grew very slowly. This scirrhous type of carcinoma is often very slow growing. A study of the microscopic sections in this case reveals the histogenesis of the cancer from the epithelium of the bronchial mucous glands. All gradations from the normal glands of the bronchi to completely unrestricted, anarchistic growth of tumor cells can be traced out in the sections.

SUMMARY

1. Carcinoma of the lung is a rare disease; but its rarity is exaggerated by the failure to recognize many of those cases that do occur. It is only at necropsy that many are revealed.

2. Carcinoma of the lung may be diagnosed clinically. However, a diangosis is possible only when careful and detailed histories are taken and accurate physical examinations are made. Laboratory and roentgenologic studies may also be helpful. All facts obtained must be carefully correlated. Statistics show that complete examinations of the patients have, in the hands of certain practitioners, resulted in correct clinical diagnosis in from 80 to 95 per cent. of the cases.

3. This disease is apparently increasing in frequency, especially during the past few years. Chronic inflammations, such as tuberculosis, are possible factors in the etiology of the disease. The last great influenza epidemic is perhaps another factor. The average incidence has been about 2 per 1,000 necropsies. In our series, during the past few years the increase has been about fourfold. The disease has formed about 2 per cent. of the cases of cancer encountered at the postmortem studies.

4. Most pulmonary carcinomas develop from the bronchial epithelium. Some originate from the bronchial mucous glands and only a few arise from the alveolar epithelial cells.

5. Epithelial metaplasia is relatively common in bronchial mucous membranes. This may explain the origin of the comparatively large number of squamous-cell carcinomas in this region.

6. Metastases are common in this disease and often are numerous. The frequency of metastases to the brain, suprarenals and thyroid is very striking.

7. Pain in the chest, cough and dyspnea occur early. Bloody sputum, cornage and asymmetry of the chest are important findings in these cases. Laboratory procedures and roentgenologic studies have thus far not proved of very great assistance in the differential diagnosis.

8. Bronchiectasis is an important complication, especially since it may give misleading physical and roentgenologic findings during the course of the disease.

9. The study of the thirteen cases reported in this paper shows the importance of assuming a new attitude toward this disease with reference to its prevalence and diagnosability. The two cases encountered at the University Hospital during the past year were both recognized clinically; but ten of the remaining eleven of this series were not diagnosed correctly. This fact points strongly to the necessity of greater familiarity with the signs, symptoms and pathology of the disease.[49]

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49. After this article had been sent to the publishers, another case of carcinoma of the lung came to necropsy at the University Hospital. This case had been studied for many months at the hospital, and had been diagnosed as carcinoma of the lung before this article had been completed; but since no cases that had not come to necropsy were included in the present study this case was not discussed. Within a period of less than one year, three patients with carcinoma of the lung have been admitted to the University Hospital and their cases have been diagnosed. The last case will be reported later.

COMPARATIVE RESULTS OF THE LIGATION OF THE HEPATIC ARTERY IN ANIMALS

ITS APPLICATION TO MAN *

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In a preliminary report [1] the reason for this study was pointed out to be an injury of the hepatic artery sustained by a boy, aged 12 years, who was run over by a wagon, the wheels passing over the epigastric region. He had all the symptoms of an internal hemorrhage. At operation, the hepatic artery was found to be severed. Both ends of the artery were tied. The boy did well until the tenth day, when he developed a slight jaundice, accompanied by vomiting. He died on the fourteenth day, of symptoms resembling acute yellow atrophy of the liver. A postmortem examination was refused. Our desire to duplicate this injury in animals has developed these experiments.

In our preliminary studies, rabbits were used exclusively; but in our later experiments, dogs, cats, guinea-pigs and rabbits were employed. These animals may be divided into the carnivorous and herbivorous types. We found the former particularly resistant to the effects of the ligation of the hepatic artery, while the latter succumbed in every instance. This difference in their susceptibility to the ligation may be due to changes in the metabolism in these two types of animals. This problem is occupying our attention at the present time and the results will be reported in the near future.

However, the anatomic variations may be a sufficient reason alone to cause such a tremendous difference in the mortality rate of the different animals. To arrive at a definite conclusion concerning the difference in the ability of these animals to resist the ligation performed in a similar manner, a study of the comparative anatomy of the four animals used was deemed essential (Figs. 1, 2, 3 and 4). It will be

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* Research work performed at the laboratory of pathology, Philadelphia General Hospital, Dr. E. H. Krumbhaar, Director; Baugh Institute of Anatomy, Jefferson Medical College, Dr. J. Parsons Schaeffer, Director. Clinical work performed at the Jewish and Mount Sinai hospitals.

1. Behrend, Moses: Surg. Gynec. & Obst. **31**:182 (Aug.) 1920.

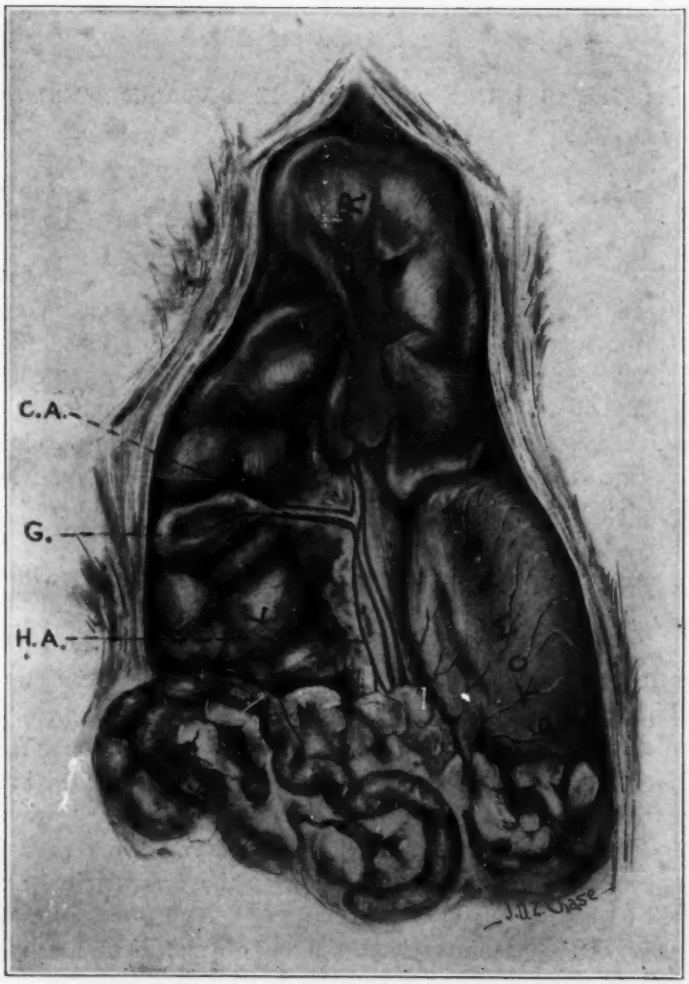


Fig. 1.—Hepatic artery of the guinea-pig. The hepatic artery is simply a line running over the gastrohepatic omentum: *C. A.*, cystic artery; *G.*, gallbladder and *H. A.*, hepatic artery.

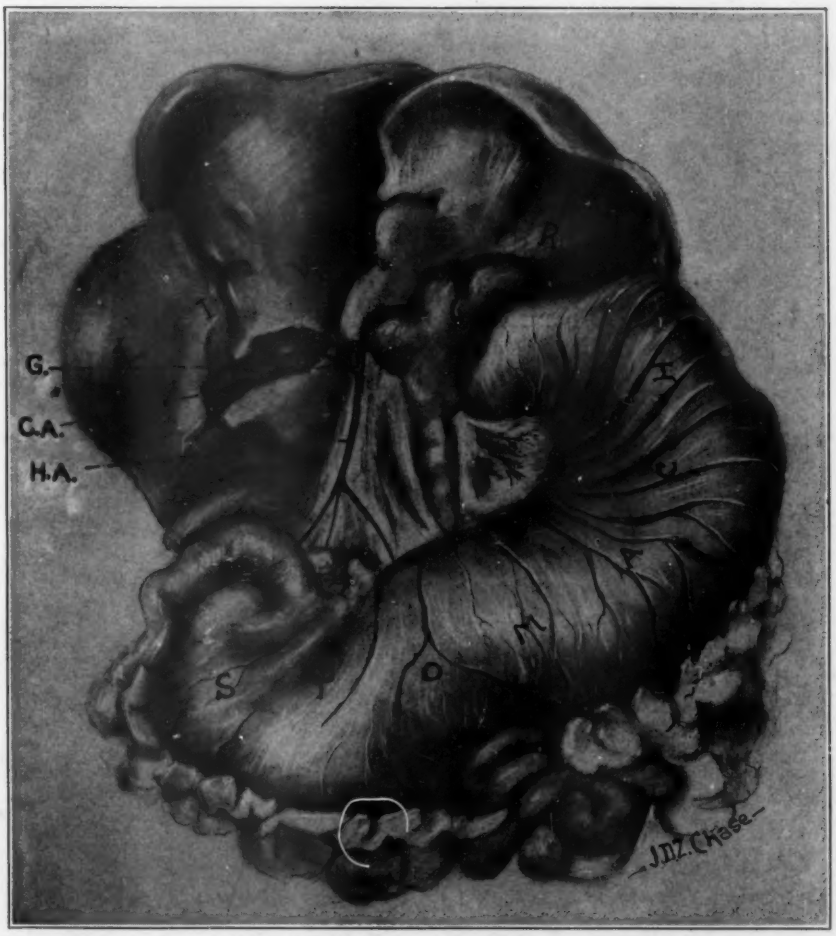


Fig. 2.—Hepatic artery of the rabbit. The single artery running over the gastrohepatic omentum may be noted: *G.*, gallbladder; *C. A.*, cystic artery, and *H. A.*, hepatic artery.

readily seen that the anastomosis of blood vessels in the cat and dog is rather intimate when compared to that of the rabbit and guinea-pig.

The anatomy of the hepatic artery and its variations in man were reported in previous papers, as well as the variations of the bile ducts.[2] These studies have shown, however, that in certain cases in which there is no anastomosis at all of the hepatic artery before it enters the liver, and in which the hepatic artery is derived from the celiac axis only, there is considerable danger in ligating the sole source of

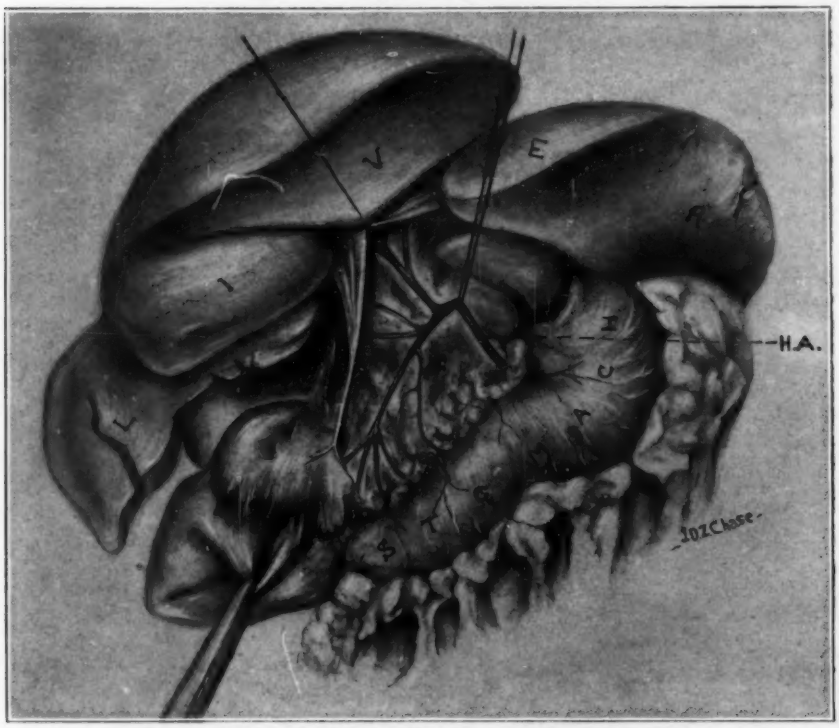


Fig. 3.—Hepatic artery of the dog. The artery runs behind the lesser omentum. The intimate anastomosis accounts for the resistance of the dog to its ligation: *H. A.*, hepatic artery.

arterial blood to the liver. This is especially true since the hepatic artery is an end artery (Figs. 5 and 6). When an accessory hepatic artery is derived from the superior mesenteric or the left gastric artery there is probably less danger to the patient, but there is no question that accidental ligation of the main vessel even in such a case exposes the patient to danger of necrosis of the liver.

2. Behrend, M.: Failure of Surgery on Extrahepatic Biliary Passages, J. A. M. A. **73**:892 (Sept. 20) 1919; Improved Technic for Removal of Gall-bladder, J. A. M. A. **75**:222 (July 24) 1920.

Our experiments have shown that if even a branch of the hepatic artery is tied there is a microscopic change in the liver cells (Fig. 7). This change in the liver cells may still be seen weeks after the experiment has been performed. Figure 8 illustrates the microscopic changes in the liver cells of a dog, killed 113 days after the ligation. The fact that degeneration of liver cells may be detected easily by the microscope even weeks afterward may explain the cause

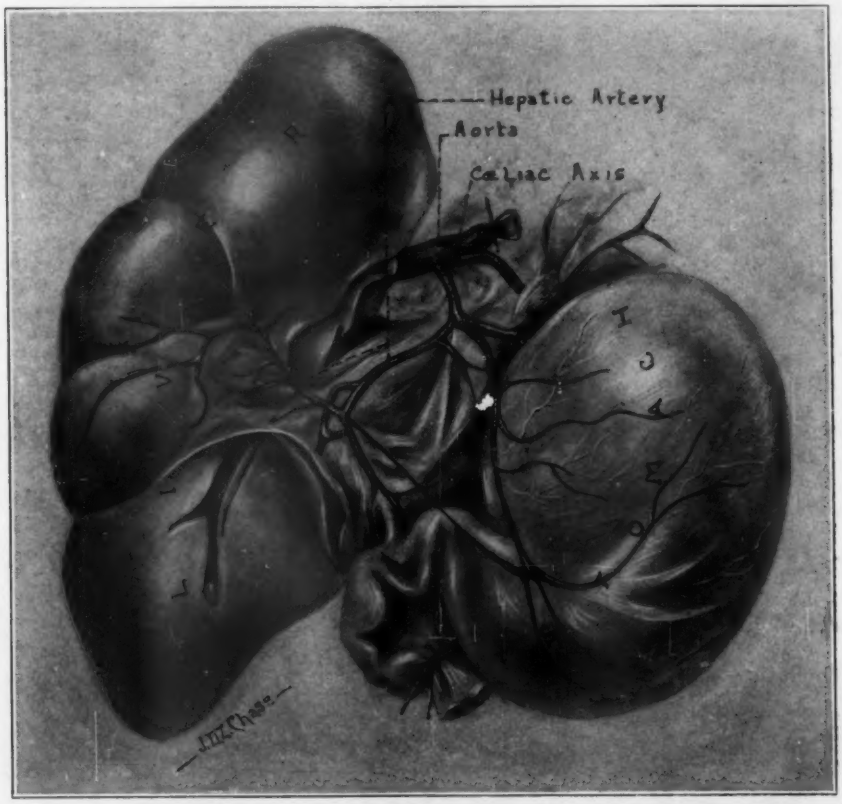


Fig. 4.—Hepatic artery of the cat. The complexity, the different branches and the anastomosis are in marked contrast to those found in the rabbit and guinea-pig.

of death of a patient who was admitted to the Mount Sinai Hospital a few months ago. About two years before admission, a cholecystectomy had been performed. The patient was brought to the hospital in an unconscious condition. Her face was tinged slightly yellow. A diagnosis of acute yellow atrophy of the liver was made, which was confirmed at necropsy. Unfortunately, before a minute dissection of the liver could be performed, the specimen was destroyed An oppor-

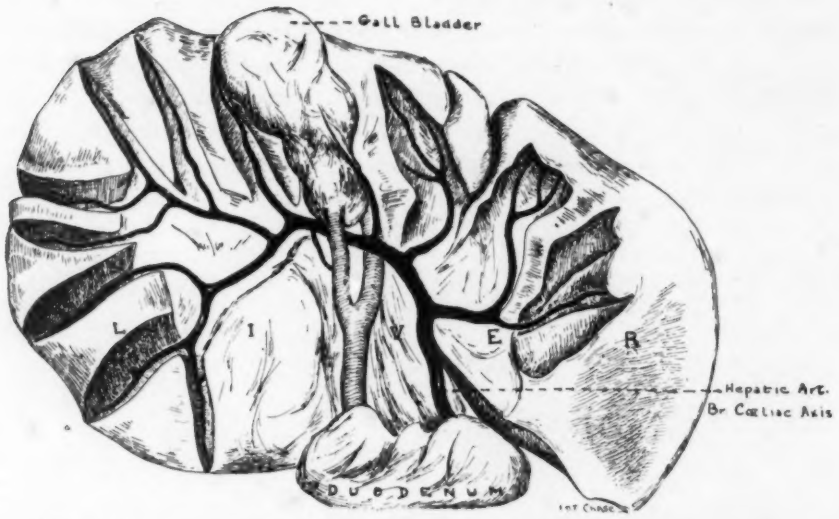


Fig. 5.—Human liver, inferior surface, illustrating the hepatic artery as a single blood vessel coming from the celiac axis. After the hepatic artery enters the liver, it terminates as an end artery without anastomosis.

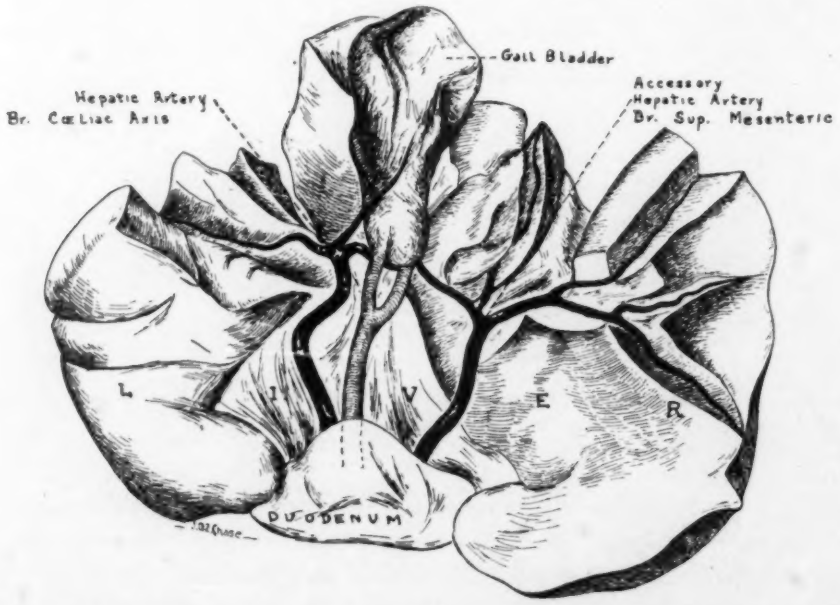
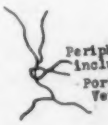


Fig. 6.—Inferior surface of human liver, showing the hepatic artery as a branch of the celiac axis; an accessory hepatic artery as a branch of the superior mesenteric artery. As in Figure 5, the liver has been dissected to show that the hepatic artery is an end artery.

tunity seldom encountered to prove our contention that ligation of the hepatic artery is fraught with the greatest danger was lost. Microscopically, the liver showed a fatty degeneration typical of acute yellow atrophy of the liver.

TABLE 1.—SITES OF LIGATION AND RESULTS OBTAINED AFTER THE OPERATION ON THE HEPATIC ARTERY OF THE RABBIT

Rabbit	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
1		18 hours		No pathologic condition noted	(No sections made)
2		4 days		Liver shows several white areas, where tissue appears cheesy in consistency extending deeply into liver	Large area of necrosis, with peripheral zone of cellular infiltration; marked dilatation of central vein of lobules; hepatic arterioles difficult to find, and show hyalinization
3			20 days	No liver changes except dense adhesions involving omentum, mesentery and under surface of liver	(No sections made)
4		5 days		Massive necrosis in area similar to Rabbit 2	(No sections made)
5		17 hours		Anemic, pale and flabby	Necrosis of cells near central part of lobules; cells stained poorly; collapse of cells
6		Died during operation		Normal	(No sections made)

As has been stated, the site of ligation of the hepatic artery and its branches is important in developing the conclusions of our study. Let us divide the steps of a ligation into the central and peripheral, or a combination of the two (Tables 1 to 6). By a central ligation is meant the ligation of the hepatic artery just as it leaves the celiac axis. By a peripheral ligation is meant the ligation of the hepatic artery

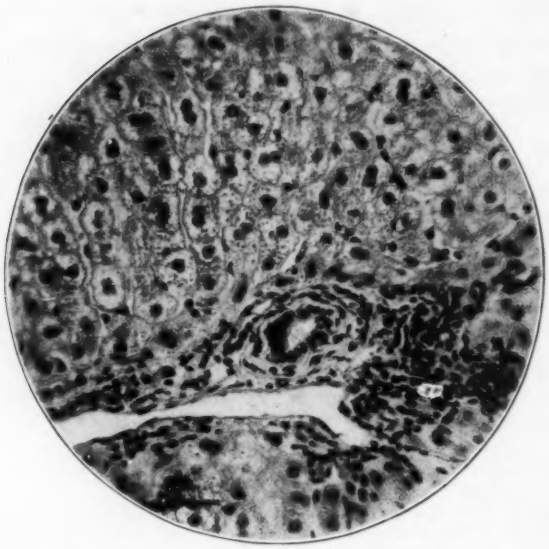


Fig. 7.—Degeneration of the nuclei as a result of ligation of a branch of the hepatic artery (Kershner).

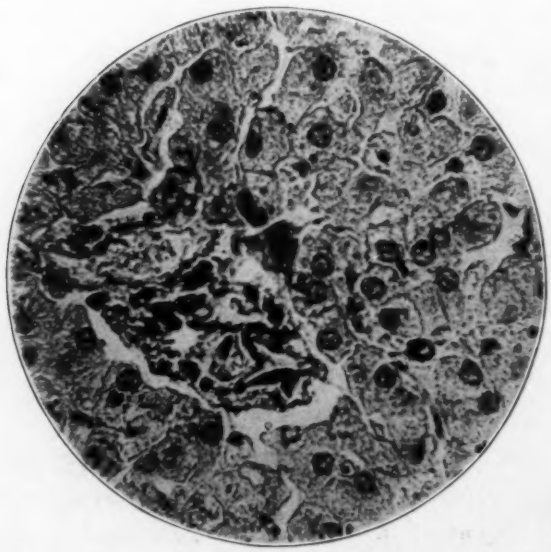
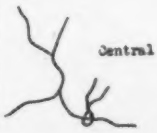
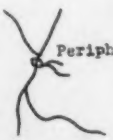


Fig. 8.—Liver of dog killed 133 days after ligation of the hepatic artery; nuclei dissolved (Kershner).

close to the liver in the folds of the gastrohepatic omentum. In a central ligation, on account of the anastomosis with the gastroduodenal and the right gastric arteries, death of the animal is not certain. This fact is confirmed in man by Chiari.[3] Rabbits and guinea-pigs may even resist a ligation of this character; but if a successful

TABLE 2.—SITES OF LIGATION AND RESULTS OBTAINED AFTER THE OPERATION ON THE HEPATIC ARTERY OF THE RABBIT

Rabbit	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
7		19 hours		No gross change noted	(No sections made)
8		18 hours		No color change	(No sections made)
9		23 hours		Massive necrosis in all but one lobe; this lobe had blood supply intact	Massive necrosis at one end of section; very little reaction against same; liver cells stained poorly; portal veins thrombosed and hugely dilated
10			50 days	Extensive adhesions; several large cheesy masses encased in liver substance; color, paler than normal	Hepatic cells stained poorly; much degeneration; central veins show dilatation
11			18 days	Adhesions	(No sections made)
12		36 hours		Characteristic necrosis, especially of lobe to which gallbladder is attached; few adhesions found	Areas of necrosis, with zones of reaction against same; dilatation of portal venules

peripheral ligation is performed in herbivorous animals, such as rabbits and guinea-pigs, all die in from seventeen hours to three or four days. This confirms our experiments reported in our preliminary note. Dogs are most resistant and live in spite of the ligations, which fact coincides

3. Chiari: Quoted by Baruch, Beitr. z. klin. Chir. **45**:502, 1915.

with the work of Whipple.[4] Kehr and Narath [5] state that fatal necrosis in rabbits is common because all the branches of the hepatic artery are easy to ligate, while in dogs it is very different because of numerous anastomoses and sources of blood supply from the diaphragm. In his dissections of the liver of the dog, Dr. Benjamin Lipshutz, working in our laboratory, found no arterial supply going to the liver from any source except through the agency of the hepatic artery as illustrated in Figure 3. Dogs and cats will show the effects of a ligation for several days afterward. They are not so playful and there is an appreciable loss in weight. Still they recover from the effects of the operation.

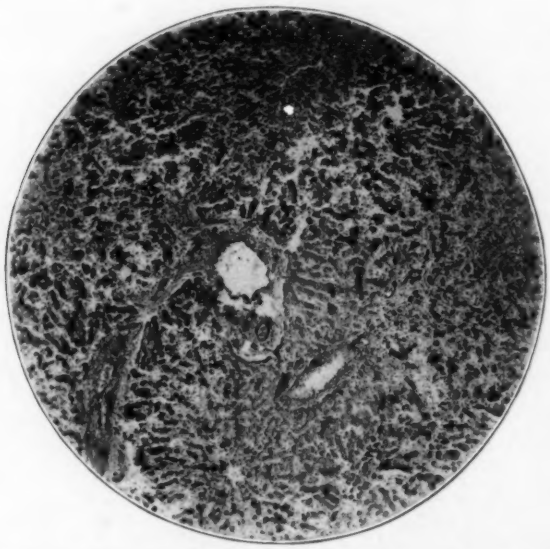


Fig. 9.—Massive necrosis of liver of cat after every vessel had been ligated that entered the liver (Kershner).

In only one cat were we able to cause death by ligation of every vessel running into the liver. This included also the ligation of the vessels of the diaphragm, which, according to some authorities, keep the animals alive after the hepatic artery has been ligated. The microscopic study of the liver of this animal showed it to be in a state of complete necrosis (Fig. 9).

The most important deductions from our studies will be their application to the human being. Naturally the experimental operation cannot be performed in man; but from our studies in the anomalies of the hepatic artery in the anatomic laboratory and at the operating table, we are convinced that the hepatic artery instead of the cystic

4. Whipple: Bull. Johns Hopkins Hosp. **20**:281, 1909.
5. Kehr and Narath: Deutsch. Ztschr. f. Chir. **135**:305 (March) 1916.

artery may easily be ligated. It is our opinion that some unexplainable deaths are due to necrosis of the liver, caused by the ligation of the hepatic artery, especially in those cases in which there is no anastomosis before the hepatic artery enters the liver and in which there is no accessory hepatic artery.

TABLE 3.—Sites of Ligation and Results Obtained After the Operation on the Hepatic Artery of the Guinea-Pig

Guinea-Pig	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
1		12 hours		Liver soft and flabby, irregular white areas	Areas of focal necrosis, hydropic degeneration; few vessels contained coagulum
2		2½ days		Liver shows irregular white areas of necrosis, cheesy and friable in consistency	Typical pale infarct, zone of reaction surrounding same; portal veins dilated; rest of tissue shows congestion and cloudy swelling
3		3½ days		Some adhesions, one lobe pale and anemic; small white areas of necrosis in rest of lobes; distinct anemic infarct, reaction against same being poor	Thrombus in portal vein; fatty infiltration and hydropic degeneration
4			9 days	Very few adhesions; no gross changes	Cloudy swelling predominating; hydropic degeneration near central vein area; sinusoids greatly injected in places
5		5 days		Irregular areas of necrosis marked; adhesions profuse on under surface of liver	No area of necrosis included in section; cells generally show hydropic degeneration; arterioles difficult to find

The deliberate ligation of the hepatic artery in man has been performed by others, and it illustrates our contention that death results following the operation. Baruch,[6] in referring to an hepatic aneurysm

6. Baruch: Beitr. z. klin. Chir. **45**:502-512, 1915.

states that the ligation of the hepatic artery is tragic on account of its lethal effect. He also reports eight deliberate ligations of the hepatic artery. Tuffier,[7] in operating on what was supposedly a hydatid cyst, opened an aneurysm of the hepatic artery. The bleeding that followed was so profuse that he was compelled to ligate the hepatic artery proximal to the aneurysmal sac. Death followed within four days. There was

Fig. 10.—Necrosis and degeneration of liver cells and cloudy swelling (Radasch).

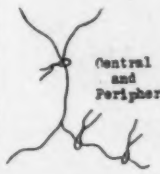
no liver necrosis; but death was thought to be due to hepatic insufficiency. Kehr's [8] patient is the only one, whose case is reported, that lived after the ligation of the hepatic artery. He states that after ligation of the hepatic artery above and below the aneurysm, the latter bled pro-

7. Tuffier: Presse méd. **17**:153, 1909; Allessadria: Bol. Acad. de med. de Roma, **32**:63-67, 1906.

8. Kehr: München. med. Wchnschr. **1**:1861-1867, 1903.

fusely after it was opened, necessitating a tight tamponade. Kehr concluded from this observation that ligation of the hepatic artery was the proper treatment. Baruch dissents from this opinion on account of the occurrence of experimental necrosis following the ligation of the hepatic artery in animals.

TABLE 4.—Sites of Ligation and Results Obtained After Operation on the Hepatic Artery of the Dog

Dog	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
1			33 days	Paling of portion of under surface of liver	(No sections made)
2			38 days	No changes noted except for adhesions in gastrohepatic region	Portal veins dilated; organizing thrombi in some vessels; liver cells swollen and fine vacuoles present; yellow, amorphous pigment present
3			35 days	None noted, except dense adhesions about gastrohepatic region	(No sections taken)
4		4 days from sepsis		Appears normal except for few small areas of gray coloration	Capsule normal; central zone of each lobule shows destruction of liver cells and replacement by cellular detritus red blood cells, and amorphous pigment; large bacilli scattered throughout detritus
5			113 days	Liver of normal consistency and color; very few adhesions	Liver cells are swollen, pale, and filled with fine vacuoles; nucleus absent in many instances; yellowish, amorphous pigment in abundance; portal veins not dilated

Narath has collected all the articles on ligation of the hepatic artery, particularly the work of von Haberer. The data disclose that the vitality of the liver depends on the site of the ligation. The more centrally the ligature is placed, the greater the chance of recovery. The results also show that ligation of a branch of the hepatic artery in most cases resulted in the death of the animal from hepatic necrosis.

If death does not follow, the necrotic area is encapsulated. All this is in conformity with our own experimental work. In addition, we found that one or two animals survived because of adhesions of the liver to the diaphragm and of the great omentum to the parietal peritoneum, forming, so to speak, an accessory anastomosis similar to that following a

Fig. 11.—Same as Figure 10, but showing a lesser degree of degeneration (Radasch).

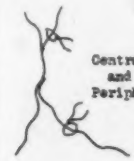
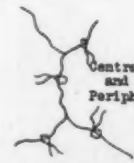
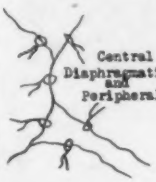
Talma operation for cirrhosis of the liver. The occurrence was so striking that our attention was directed to this phenomenon.

TECHNIC

Prior to operation all animals were shaved, tincture of iodin was applied to the skin, and then the field of operation was surrounded with a sterile sheet. The instruments were boiled between operations, when more than one was per-

formed on the same day. The hands were thoroughly scrubbed. Gloves were not used. Ether anesthesia was used altogether, except in the case of cats, when chloroform was employed to induce stupor only, after which ether was given. Chloroform was tried on dogs, but they were so susceptible to it

TABLE 5.—SITES OF LIGATION AND RESULTS OBTAINED AFTER OPERATION ON THE HEPATIC ARTERY OF THE CAT

Cat	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
1			23 days	No changes noted	(No sections made)
2			23 days	No changes noted	(No sections made)
3			20 days	Liver shows no gross change; gallbladder thickened and tough; adhesions	Hydropic degeneration of liver cells; immediate subcapsular region is congested; some central veins contain coagulum; portal veins dilated
4			19 days	Dense adhesions in region of gallbladder; no other changes noted	Capsule normal; central veins congested; liver cells generally show hydropic degeneration, but are best preserved in subcapsular areas
5		48 hours		Soft, succulent, and paler in some areas than in others	Universal necrosis

that we were compelled to use ether exclusively. Silk was used in all ligation; the wounds were closed with catgut and silk sutures. A pad was always placed at the border of the ribs posteriorly so as to render the structures around the foramen of Winslow nearer to the field of operation.

MORPHOLOGIC AND HISTOLOGIC REPORT

The following morphologic and histologic report by one of us (Dr. Radasch) describes the results of our experimental work mentioned in the preliminary note. In the main, these descriptions were confirmed in our final experiments.

The necropsy of one of the rabbits that died between four and five days after ligation showed that the liver had undergone serious changes. Between

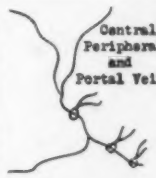
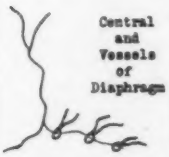
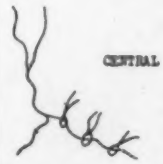
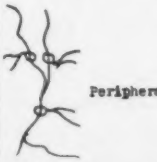
Fig. 12.—Parenchymatous degeneration; portal canals unusually prominent (Radasch).

the right lobe and the diaphragm, there was a layer of light yellow material that seemed to be necrotic liver tissue. The left lobe of the liver was mottled with reddish and whitish patches. The cardiac part of the stomach also showed a yellowish patch.

The surface of sections showed a thick layer of granular material which under the higher power was seen to consist of many leukocytes (chiefly polymorphonuclear cells and some lymphocytes) and necrotic substance. In

some areas, the cells predominated and in others the granular necrotic material was predominant. Separating this necrotic layer from the liver cells was the scarcely perceptible capsule of the liver. In places the capsule seemed absent and the liver cells underneath had undergone a degenerative change in varying degrees; some were entirely destroyed, while others were very nearly so, or showed only early changes. Many areas of focal necrosis were noticeable and

TABLE 6.—SITES OF LIGATION AND RESULTS OBTAINED AFTER OPERATION ON THE HEPATIC ARTERY OF THE CAT

Cat	Site of Ligation	Death Following Operation	Death by Chloroform	Liver Changes	
				Gross	Microscopic
6		18 hours		Pale, soft and flabby	Total necrosis
7			14 days	Many adhesions; two lobes of liver a degree paler than normal	Portal veins injected; central veins distended; hydropic degeneration of liver cells; no massive necrosis
8			63 days	Many adhesions; liver considerably paler than normal; no change in consistency	Irregular focal necrosis in central parts of lobules; hydropic degeneration of cells toward periphery of lobule; some enlargement of all the vessels
9			40 days	Liver much paler than normal; gallbladder apparently normal; inferior surface of liver shows small, pale, raised areas	Cells swollen and pale; certain areas contain irregular, clear vacuoles; nuclei generally pale, and some entirely missing (hydropic degeneration)
10			27 days	Adhesions but no other changes	(No sections made)

some of these were quite large and chiefly subcapsular. The hepatic cells in general exhibited parenchymatous changes, especially the nuclei. The latter responded very poorly to the stain. Some of the larger biliary ducts showed changes. The epithelium was partly desquamated and the remainder showed cloudy swellings (Figs. 10 and 11).

Another section of liver from a rabbit that lived five days after the operation showed a somewhat thickened capsule and the cells showed proliferation on the deeper surface. The hepatic cells in general showed parenchymatous degeneration to a marked degree. There were a few small necrotic areas, and small groups of round cells were noted. The cell chains were very much attenuated in places, and the cells showed atrophy. The portal canals were unusually prominent (Fig. 12).

Fig. 13.—Most extensive changes. The liver in fresh state showed many small holes (Radasch).

Another section exhibited the most extensive changes so far studied. Even in the fresh state (at removal), the liver showed many small cavities that communicated with one another. In section this condition was emphasized and gave the appearance of having been riddled with shot. The same section represented the thin margin of the liver, and with the unaided eye the numerous small spaces left by the removal of the necrotic tissue gave characteristic appearance to the section. The capsule showed very little thickening, and the mesothelium for the most part was absent. Most of the remaining hepatic epithelium showed marked parenchymatous degeneration. A few cells gave

a good nuclear stain, but these cells were mostly small and atrophic with enlarged sinusoids between them. The portal canals all stood out prominently and in some of these areas the branches of the bile ducts showed desquamation of the epithelium. In the interlobular tissue of the portal canals an unusually large number of thin walled blood vessels of considerable caliber may be noted (Fig. 14).

Conclusions.—(Dr. Radasch).—The lesion resembles somewhat the changes that occur in acute yellow atrophy of the liver. The diminution in size is not so marked, but the mottling is apparent.

While the microscopic changes in acute yellow atrophy usually show fatty degeneration and the presence of fat droplets and hyaline material, in the section studied there seemed to be an absence of fatty material of all kinds. The cells have undergone a rapid parenchymatous and necrotic change so that the architecture is destroyed and there remains only an amorphous mass of granular necrotic material. The term "necrobiosis" seems well chosen to express the condition, as a "living death" seems to be exemplified in the shrinking and degenerating cells.

This result of ligation of the artery seems to indicate an acute anemia of the liver. The hepatic vessel is far too small a vessel to act as the nutrient vessel of the organ, that is the function of supplying the liver with food.

The liver is an important oxidizing organ. The various toxins formed by the putrefaction of proteins in the intestines are brought to the liver by the portal vein, and through the action of the liver cells, these substances are oxidized and rendered harmless substances that the kidneys later eliminate. If the liver cells are deprived of this and other oxygen, they cannot perform these chemical changes, and also degenerate as the result of the presence of these toxins and the inability to repair their own wear and tear.

It would appear that any injury which prevents the proper amount of oxygenated blood from getting into the liver gives rise to an acute anemia that is followed by general necrobiosis of the hepatic tissue.

GENERAL CONCLUSIONS

Ligation of the hepatic artery is dangerous at all times. This has been proved in the few cases reported in which a deliberate ligation in man was one of necessity on account of aneurysm or other pathologic conditions. (Only one patient recovered [Kehr's].)

There is a varying susceptibility of animals to the effects of ligation of the hepatic artery. This depends on the point of ligation to a certain extent, namely, whether the ligation is made centrally or peripherally.

Rabbits and guinea-pigs always succumb to successful peripheral ligation. Dogs and cats resist the ligation and continue to live indefinitely in spite of a combination of a peripheral and central ligation.

An important point to be kept in mind is that histologically we have found degeneration of the liver cells in all animals in which ligation was performed.

INGUINAL HERNIA: A STUDY OF THE PRINCIPLES INVOLVED IN THE SURGICAL TREATMENT

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BAHREIN, PERSIA

There is no lack of recent literature on the subject of inguinal hernia, and no lack of variety in the operations suggested for its relief. All manner of technical procedures have been described; and varying degrees of success have been reported. These articles, however, have dealt with details. There has been a surprising absence of any effort to submit the principles governing all the accepted operative procedures to a really adequate analysis and criticism.

ANATOMY

The abdomen forms a closed sac, and its walls are exposed to a slight constant intra-abdominal pressure. In addition to this, whenever the trunk is in the upright position, the lower part of the abdominal wall must withstand a supplementary pressure approximately equal to that of a column of water 25 cm. high. If observations at operation can be trusted, these factors are trifles compared with the strain put on the wall in coughing, heavy lifting, etc. Under these circumstances, the intra-abdominal pressure, for a brief period, must reach a much higher figure.

PATHOLOGY

In certain places, the abdominal wall sometimes proves unequal to the strain put on it, and a hernia develops. The most frequent site of such a failure is the internal abdominal ring, and next to it, Hesselbach's triangle. Femoral hernia is much less common, and occasionally we see a hernia through Petit's triangle, and in many other places.

It is a matter of some importance to find out which of the structures forming the abdominal wall is at fault when it gives way. The problem is most easily studied in direct hernia, in which the beginning of the process is not infrequently observed. I have had occasion within the last year to operate in two very early cases of direct hernia. In these two patients, there was no noticeable bulge on coughing or straining. Following heavy lifting, the patient complained of pain in the region of the external ring, which recurred on exertion, and which in the few days since the onset had been growing worse. A tentative diagnosis of beginning direct hernia proved correct in each case, and although at operation the muscular structures of the abdominal wall seemed to be quite normal in development and arrangement, the transversalis fascia was found to be giving way over an area, in one

case, the size of a dime, and in the other case, nearly the size of a nickel. The area of defective transversalis fascia was sharply defined and the bulge had reached the size of half a small hickory-nut in one case, and somewhat less than that in the other. There was no abnormality in the other structures of the abdominal wall. The other early cases that I have seen have been farther advanced, with a definite sac, and with the structures of the wall correspondingly displaced. Whether the fascia in question was congenitally weak or whether the strain of heavy work had injured a normal structure, it was not possible to say. There could be no doubt, however, that the essential factor in the pathology of the condition was a change in the transversalis fascia, and it was equally evident that the lesion was sharply limited, the remaining part of the transversalis fascia, exposed by the operation, showing no tendency to give way.

The observations mentioned above contribute nothing new to our ideas regarding direct hernia, for it is generally supposed that a direct hernia results from an insufficiency of the transversalis fascia. No such unanimity, however, obtains as to the cause of indirect hernia. Here there is much confusion in present day surgical thought. It is most unfortunate that we have had our attention centered on the vaginal process and its theoretical persistence after the descent of the testicle. Such an abnormally persistent processus vaginalis is assumed in the case of every man that later develops an indirect hernia. When we consider the dozens and hundreds of men who first show a hernia at 50 and 60, after their active life is over, the hypothesis becomes improbable, to say the least. However, the main objection to the theory is that, even if true, it gives us no useful guidance. In and of itself the persistence of a more or less elongated, narrow processus vaginalis would not predispose to a future hernia, if all the elements of strength present in the wall of the abdomen were also present in the wall of the process. Indeed, if its wall were of equal strength, it would enjoy a slight mechanical advantage, for the abdominal contents are not absolutely fluid, and its narrow mouth and elongated shape would serve to shield it somewhat. If such an extension of the abdominal wall is more inclined to give way than the wall generally, it must be because it lacks some element of strength that the main wall possesses, and the important thing is to find out what that lack is.

We have had no opportunity to observe the earliest stages of an indirect hernia. The most recent have been some weeks or months old, and have shown a distinct bulge at the external ring. Possibly in its very early stages, an indirect hernia does not cause so much pain as a direct hernia, and therefore is not so likely to come to operation. In these early cases of indirect hernia, there is already a widening of the inguinal canal and a displacement of the muscular and fascial struc-

tures that bound it. The muscles, however, appear to be normal in size and strength. The floor is formed by a conjoined tendon, apparently normal in strength and thickness, as are the internal oblique muscle and the pillars of the external ring. We frequently see an indirect hernia coming through an abdominal wall, much superior in the strength of its musculature and the snugness of its external ring to many walls that show no hernia. The impression is very strong that the displacement of the muscular and fascial structures accompanying an indirect hernia is the effect of the hernia and in no sense its cause.

This conviction is much strengthened by a consideration of the further development of such a hernia. A Bedouin boy fell from his camel, and, following the accident, an inguinal hernia began to develop. Six months later, he reported to the Mason Memorial Hospital with the largest hernia that has ever come under my observation. It reached below the knees. Such a history, however, is exceedingly rare. Usually the pressure-resisting capacity of the abdominal wall at the internal ring does not drop to zero or anywhere near it. It barely sinks under the necessary 100 per cent. and a hernia develops, the growth of which proceeds very slowly and in most cases stops altogether after a time. In ninety-three hernias in which this matter was investigated, fifty-seven had ceased to enlarge after a longer or shorter period, and there had been no increase in size since. This is a country where the influence of trusses may be disregarded. The external ring in some of these cases was very large, the hernia recurring immediately after reduction, in other words, the laws of fluid pressure must have been practically 100 per cent. effective. Indeed, the same conditions are found in those infrequent hernias that are partially or wholly filled with fluid, and in which the laws of hydrostatic pressure must be quite unmodified.

The weakness of the wall in such a hernia has become compensated and the hernia withstands the intra-abdominal pressure adequately. It does so, however, with no help from the muscular abdominal wall. A hernia of long standing shows two layers, which apparently are the effective agents in withstanding the intra-abdominal pressure: an external fascial layer that is continuous with the external oblique fascia, and an inner layer, intimately connected with the peritoneal sac itself. The scattered fibers of the cremaster muscle cannot be considered as rendering any significant help.

The natural conclusion is that the cause of an indirect hernia, as of a direct hernia, is the failure of the transversalis fascia to withstand the intra-abdominal pressure to which it is subjected. It is not surprising that of all the transversalis fascia the weakest spot is the place where its continuity was interrupted in fetal life to allow the descent of the testicle. There is no reason to assume the persistence of an open

processus vaginalis in every case, in the absence of any demonstration of such a phenomenon. The descent of the testicle must certainly leave the fascia weak in this locality; and this would seem sufficient to explain the fact that here it most frequently gives way.

A second conclusion is that once the transversalis fascia gives way, the muscular abdominal wall offers no effective obstacle to the growth of the hernia, and that compensation is eventually established with no help from that wall, but by a hypertrophy of derivatives of the transversalis and external oblique fascias.

If hernias occur because of the failure of the transversalis fascia to withstand the pressure to which it is subjected, the natural method of operative correction would seem to be the repair and strengthening of that fascia. The surgical attack on the problem, however, has developed along an entirely different line. Previous to the appearance of Halsted's article in 1889 and of Bassini's article in 1890, it could hardly be said that any coordinating idea existed. Those two articles laid down the main principles of procedure that have been followed ever since; first, that after removal of the hernial sac, its recurrence is to be prevented by a repair of the muscular and fascial structures of the abdominal wall; and second, that the principle feature of this repair is a solid attachment between the internal oblique muscle and the conjoined tendon on the one side, and Poupart's ligament on the other. Around this central idea, every imaginable technical variation has been advocated, each constituting an enormous improvement in the mind of its sponsor, and proving to be no improvement at all in the hands of anybody else. The cord has been brought out below, in its normal position close to the pubic bone, and it has been transplanted and brought out higher up. When thus transplanted it may be placed between the internal and external oblique muscles, or it may be placed subcutaneously. The medial leaf of the external oblique fascia has been sutured above Poupart's ligament, and it has been sutured below it. The cord has been brought out through a single opening, and it has been separated into veins and vas, and brought out through two smaller openings. Postures for the patient have been studied whereby the hiatus between the conjoined tendon and Poupart's ligament can be reduced. An untried technical rearrangement of the available material can scarcely be imagined, but always under the guidance of the two principles that Halsted and Bassini laid down.

It is unlikely that anything is to be gained by further efforts along this line. The two principles introduced by Halsted and Bassini have done, for the surgery of inguinal hernia, all that they are capable of doing. There is, indeed, a rather surprising lack of precise information as to what this procedure does accomplish. Any one who has had occasion to operate on recurrent hernias knows that it does not accom-

plish what is usually supposed. We do not produce an abdominal wall where a close apposition of the internal oblique muscle and the conjoined tendon on the one side and Poupart's ligament on the other prevent the recurrence of a hernia. What we produce is a mass of scar tissue, densely adherent on the external side to Poupart's ligament, on the internal side to the internal oblique muscle and the conjoined tendon, and below to the pubic bone. Through this plate of scar tissue, the spermatic cord makes it exit, either higher up or lower down, according to the type of operation performed.

Compared with conditions before the articles of Halsted and Bassini appeared, results have been very good. Compared with any permissible ideals of the present, they are bad. They are certainly not nearly so good as we have supposed. Johns Hopkins Hospital estimates its recurrences in the neighborhood of 10 per cent., and the Massachusetts General Hospital reports 8 per cent. of recurrences in cases followed and examined. Series of private cases from the upper classes, with no investigation of end-results, are not to be weighed against these figures. It is not likely that improved technic has much to offer us over what these two hospitals report. Apparently these figures represent the limit of development of this method of attacking this problem. A detailed analysis of published results would undoubtedly show that present methods are adequate for the hernias of children, reasonably satisfactory for small indirect hernias, and very unsatisfactory for direct hernias, and for those cases with large external rings and atrophied conjoined tendons.

The experience of the late war is interesting in this connection. It seems regrettable that the unique opportunity for a thorough study of the whole hernia problem was not realized. We shall hardly have such an opportunity again. However, one war-time conclusion is worthy of note from the standpoint of this article; namely, that the important point in the operative procedure is a high dissection of the sac, the treatment of the abdominal musculature being a comparatively minor matter.

TECHNIC EMPLOYED AT BAHREIN

Before proceeding to describe the operation for hernia that has been developed in the Mason Memorial Hospital, a word more must be added regarding the anatomy of a hernia. A hernia of some years' standing shows a well developed fascial layer, intimately associated with the peritoneal sac, and a second layer springing from the external oblique fascia. These layers, however, are not absolutely uniform in strength and thickness. Over the neck of the sac, they are thickened and more or less fused. Apparently, owing to this local hypertrophy, the hernial sac, however large it may become, always retains its comparatively narrow neck. Even when the external ring is large and the contents

slide in and out with no obstruction, there is little tendency for the neck to enlarge. Lower down, the fascia gradually thins out and coincidentally the neck widens into the diameter of the sac.

In the operation that we use in Bahrein for inguinal hernia an effort is made to repair and strengthen the transversalis fascia. Local anesthesia is used (procain and epinephrin), except in small children. Silk is used for suture material. The skin is cleaned with alcohol, painted with iodin, and varnished. A layer of sterile gauze is laid on the varnish, and the usual incision is made through it and carried well down over the pubic bone to make possible a good exposure there. I have found that with this technic, there is no need of fearing the filthy condition of the skin in this region. The skin of the Arab is dark, and iodin appears to cause no trouble. The external oblique fascia is split in the direction of its fibers, up from the external ring as far as seems indicated. The peritoneum is grasped high up, next to the internal oblique muscle, and its isolation is carried to the level of the pubic bone. At this point, the sac is opened, the intestines are replaced in the abdomen if necessary, and the neck of the sac is reinjected with anesthetic solution from within, as high up as desired. The neck of the sac is then completely isolated from surrounding structures, and the sac is amputated. No effort is made to dissect the sac out and remove it, except in unusual cases. I have left the sac in this manner many times, and have yet to see a hydrocele or any other untoward result. The dissection of the neck of the sac is then carried very high up. There is a lack of precision on this point, in textbooks and in special articles as well. Every one emphasizes the importance of a high dissection of the neck of a hernial sac, but no one gives definite standards or landmarks. A dissection which does not demonstrate the deep epigastric vessels, I regard as insufficient. Frequently, they must be pushed back, if the dissection is to be carried beyond the limits of the sac to normal peritoneum and transversalis fascia. This dissection constitutes the first part of the operation.

The second part of the operation, namely the repair, is begun by dividing the neck of the sac into an upper and a lower leaf, by means of two lateral divisions. The lines of division are carried down on each side, well to the limit of the dissection. The lower leaf is then carried up inside the abdomen for an inch (2.5 cm.), or more, to the limit of the operative field, pulled fairly taut, and sutured into place. The upper leaf is carried down, overlapping the lower, and sutured to the lowest point that the dissection makes available. The overlap should amount to at least an inch (2.5 cm.), or an inch and a half (3.8 cm.). Care must be exercised or the deep epigastric vessels may be injured. It is the hope that normal peritoneum and transversalis fascia from above and below will be overlapped by this procedure,

and in many cases, I am certain that they are. When the external ring was too large to permit this, the leaves of thickened fascia and peritoneum of the neck of the sac have been overlapped from above and below, leaving a doubled layer which stands ready to withstand the intra-abdominal pressure.

Following this, the cremaster is sutured under the internal oblique muscle and the conjoined tendon, a procedure described by Dr. Halsted in 1893. I believe that the cremaster muscle so placed is a help in retaining the sutured parts in position until solid healing has occurred. In some cases after the peritoneum with its transversalis fascia has been overlapped from above and below and sutured in place, the patient is able by coughing and straining to force omentum out of the angles of the overlap. After suturing the cremaster muscle under the internal oblique muscle and conjoined tendon, the repair is beautifully snug and efficient. I make it a rule to test the operative repair at this point by having the patient cough violently and strain. I believe that the test is of considerable value. The cremaster muscle may not contribute anything of great value to the permanent repair of the hernia. If the ideas outlined above are correct, its contribution in any case should not be needed. Its effectiveness, however, in holding the repaired parts in place and making the repair completely effective during the days immediately following the operation, no one can doubt who has tested it in this way.

This practically completes the operation. The external oblique muscle is repaired, restoring the external ring, which I endeavor to leave more or less normal in size. I do not try to make it unusually snug, being careful to avoid any pressure on the cord at this point. The operation has already traumatized the vessels of the cord, and every effort is made to reduce further insults to a minimum. The subcutaneous tissue is united and the skin sutured.

Direct hernia I regard as presenting a distinct problem from that of an indirect hernia described above. The fascia of the neck of a direct hernia shows little tendency to hypertrophy, and the vascular layer of fat which lies between it and the peritoneal sac leads nearly always to a fairly complete destruction of the transversalis fascia before the sac is isolated and disposed of. Thus the operation leaves a considerable defect in the transversalis fascia; and under such circumstances, a recurrence is to be anticipated. The commonly used operations for indirect hernia have given better results than those used in direct hernias for the dissection does not destroy the transversalis fascia, and if it is carried up to the region of the hypertrophied fascia of the neck of the sac, or higher still, to the region of normal transversalis fascia, we have the materials for an efficient repair. A simple ligature around the

neck of the sac is far from being an ideal means of repairing the fascia; but with a smooth primary union, the results show that it has been effective in 90 per cent. of the cases.

Whether the theory as outlined above is correct or not, there is no question concerning the fact that recurrences after operations for direct hernia are very common. Downes definitely recommends that certain types of such hernia be treated by trusses. We have had the same experience as others. To operate on a small direct hernia and have it promptly recur as a much larger and more troublesome affair, is a very disquieting experience.

The operation for a direct hernia used here in Bahrein is the same as that for an indirect hernia, until we come to deal with the sac, which is entirely isolated. Every effort is made to preserve the transversalis fascia while cleaning off the peritoneal sac. Practice has improved the technic and the results; but the results are far from uniformly successful even yet. As the peritoneal sac is often quite tough and substantial, it is split into an upper and lower leaf, and overlapped as described for an indirect hernia. The transversalis fascia is then sutured over it, or, indeed, overlapped if there is sufficient material for that. The most important feature of the operation, however, is the step that follows. A piece of fascia lata an inch (2.5 cm.) square, or larger, if necessary, which has been previously removed from the thigh, is then sutured carefully into place, reinforcing the transversalis fascia over the weak area, and overlapping normal fascia on every boundary. The size of the transplant required can be readily ascertained before the operation by examination of the patient. We do not attempt to suture this fascia under tension. The effort is made rather to fasten it accurately in the location desired, and the cremaster muscle is then sutured under the internal oblique muscle and the conjoined tendon, to carry the strain of coughing, straining, etc., until healing is solid and complete. This transplantation of fascia is a very simple procedure, adding not more than fifteen minutes to the time required for the operation, and I have yet to see a transplant that made the least trouble afterward. Hernias which are composed of a direct and an indirect sac are treated by division of the deep epigastric artery and the repair completed as in a simple direct hernia. Recurrent hernias are treated as direct.

RESULTS

Nov. 1, 1921, the operations described had been in use for nine months, during which time 201 hernias had been repaired by this method: 142 indirect hernias, and fifty-nine direct. The Mason Memorial Hospital is located in a very sparsely populated country, and is the only place where surgical service is to be obtained for hundreds of miles, in practically any direction. As might be expected, patients

who travel these long distances are usually those with severe lesions, and the cases of hernia form no exception. They are usually men of middle age, or older. The average age in this series, including children, was 43 years. Arabs and Persians practically never know their ages, and the figure given is the average of the physician's estimate for the different patients. The average duration of the hernias, excluding those which were congenital, was seven and one-half years. Thirty-six were recorded as being as large as coconuts, or larger; and of these four were extremely large, one reaching to the level of the patella, and three others to within 2 or 3 inches (5 or 7.6 cm.) of its upper border. The external ring admitted the tips of three or more fingers in thirty-five cases, and the conjoined tendon was atrophic in fifty-six cases. By this I mean that the examining finger slipped without difficulty through the external ring to the posterior aspect of the pubic bone. Six were sliding hernias, cases being so designated only when practically the whole of the posterior wall of the sac was composed of adherent cecum, colon, and the terminal part of the ileum. Three in the series were strangulated hernias; but, during this period, we were fortunate in receiving the strangulated cases early, before gangrene of the bowel had occurred, so that operatively they differed in no significant way from the others.

Technically, the series is not one of which to be proud. Two of the wounds suppurated. In one of these, the incision passed across a long narrow brand, a few days old. This is a favorite Arab treatment for almost anything, hernia included. It was one of the three strangulated hernias, so the operation was undertaken after a careful cleaning of the infected ulcer. The resulting suppuration was superficial, and the final result was good. The other case of suppuration was due to some grave error in technic. There were eleven insignificant suture infections, including those in two patients who reported to the clinic after their discharge following the removal of sutures. There were three serious hematomas, and a number of small ones. There were four deaths, one from an epidemic of infectious diarrhea in the hospital, one from heat stroke, a day or two before the expected discharge of the patient, and one from postoperative pneumonia. The fourth was the result of one of the hematomas mentioned above. About the fifth or sixth day, a patch of gangrene developed at the bottom of the scrotum, septicemia set in, and the patient died on the tenth day.

Previous to the adoption of the new operative procedure, our results had been far from satisfactory. Our hernia list has grown during the past four years, from 150, more or less, to nearly twice that figure for the past year. No follow-up system is possible in Arabia, where such things as posts and telegraphs are utterly unknown, and where probably not one in ten of the patients can read

and write. There is no way of knowing the exact number of recurrences. We have been accustomed to operate in about a dozen cases of recurrence in the course of the year. We have used both the Halsted and the Bassini operations. The immediate predecessor of the present operation was Hoguet's modification of Bassini's operation, in which the medial leaf of the external oblique fascia is sutured below Poupart's ligament, along with the conjoined tendon, and the internal oblique muscle. With increasing experience, the number of recurrences seems to have diminished somewhat, in spite of the larger number of operations performed, which indicates a considerable percentage of improvement. So far as could be seen, however, the improvement was due to an increasingly high dissection of the neck of the sac, rather than to modifications in the treatment of the abdominal wall. We consoled ourselves with the idea that considering the type of hernias dealt with, perhaps no better results could be expected.

Since adopting the operation described in this article, we have yet to see a recurrence. The series includes four patients with recurrent hernia whose original operations antedated the introduction of the new procedure; but the operation as described has yet to be followed by a recurrence. Nine months is too short a time, by far, to justify definite conclusions, and 200 hernias form far too small a series. I believe, however, that results so satisfactory in hernias of this type go far to indicate the correctness of the principles on which the operation is based, and possibly justify the publication of these results, in the hope that the operation may be tested by other men, in cases in which follow-up systems will give more positive conclusions as to its merits.

AN UNUSUAL CASE OF INTESTINAL OBSTRUCTION

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The case herewith reported presented a condition which I had never previously encountered, nor have I been able to find a similar instance reported in the literature.

REPORT OF CASE

History.—W. M., boy, white, aged 11 years, admitted to the Johnston-Willis Sanatorium, Nov. 25, 1920, with an unimportant family history, had had mumps and pertussis and, two years previously, typhoid. His appetite was good, and previous to the present illness the patient had never suffered from any attacks of abdominal pain, vomiting, or diarrhea. November 20, the patient was suddenly seized with severe, generalized abdominal pain. He soon became nauseated and is said to have vomited steadily for two hours. At the end of this time, the pain gradually subsided and soon ceased entirely. There was no recurrence of the pain until November 24, when an attack similar to the first occurred. Examination at this time revealed an oblong mass, about 4 inches (10 cm.) long, in the right lower quadrant of the abdomen. The pain diminished, but some pain persisted until the following day, when the patient was admitted to the hospital.

Examination.—The patient did not seem sick. He was well developed and well nourished. The lungs were clear both on percussion and auscultation. The heart showed no enlargement or murmurs. The abdomen was symmetrical and lay slightly above the level of the ribs. There was definite, slight tenderness in the right lower quadrant. Also in this region, a moderately hard mass, suggestive of an old appendiceal abscess, could be palpated.

The white cell count was 16,000. The Wassermann reaction was negative. The urine was amber, clear and acid, with a specific gravity of 1.021. There was no sugar and a very slight trace of albumin. Sediment showed an occasional epithelial and pus cell.

The history very obviously suggested a diagnosis of recurring attacks of intestinal obstruction. The common causes of recurrent intestinal obstruction in children are intussusception or adhesions resulting from appendiceal inflammation. In this case, the palpation of a mass in the right iliac fossa, together with the fact that the leukocyte count was 16,000, led to a provisional diagnosis of partial obstruction from appendiceal abscess, though the possibility of intussusception was borne in mind. Since the child did not seem ill, it was deemed best to delay operation so that if an abscess were present sufficient time would pass for it to become definitely walled off.

Operation.—November 27, the leukocyte count had fallen to 6,000; the temperature was 98.6 F., and the pulse was 98. The condition seemed favorable for operation.

Fig. 1.—Appearance of tumor before incision of membrane.

Fig. 2.—Membrane incised longitudinally, revealing coils of small intestine.

Under ether anesthesia, a right rectus incision was made. It was seen that the mass which was palpated at the time of the patient's examination was due to an enlargement of the lower portion of the ileum, above the ileocecal junction, the enlargement suggesting strongly the presence of an intussusception of this portion of the bowel. The mass lay entirely in the pelvis; and, in order to deliver it, the incision had to be enlarged. Upon delivery, the mass was found to be about 6 inches (15.2 cm.) long and 3 inches (7.6 cm.) across, somewhat ovoid in shape. The covering resembled the visceral peritoneum, except that it was somewhat paler. Palpation produced a doughy sensation, similar to that felt on palpation of an intestine filled with ascarides. Careful inspection showed that what was at first thought to be a dilated intestine, representing the intussuscipiens of an intussusception, was in reality a sac, formed from a membrane which appeared to cover the whole of the small intestine. Above and below the sacculated portion, this membrane was quite closely approximated to the intestine, somewhat like a loosely fitting glove finger. This sheath could be slipped about an inch (2.5 cm.) in either direction, downward or upward; further movement was then prevented by some connection which existed between the wall of the intestine and the inner surface of the sheath. The sacculated portion was split longitudinally, in the direction of the mesentery, and it was found that within the sac there were 30 inches (76.2 cm.) of small intestine, much coiled and folded, the terminal portion showing multiple diverticula. There were no adhesions between the adjacent coils of intestine; but a few delicate strands of connective tissue ran from the intestine to the inner surface of the sac. The redundant portions of the membrane, forming the sac, were trimmed off, freeing the contained intestine. It was deemed unnecessary to interfere with the portions of the membrane above and below the sacculated portion.

COMMENT

It was apparent that the cause of the recurring attacks was a displacement of the mass of intestine contained in the sac. When this mass was fitted down into the pelvis, it caused no symptoms; when it was displaced upward, it caused an angulation of the intestine and the consequent obstruction. The explanation of the nature of the membrane is not so simple. The absence of any evidence of an inflammatory process indicates that the condition was the result of some developmental defect. Histologic examination of a portion of the membrane made by Dr. S. W. Budd showed that it was made up of fibrous tissue. Dr. Budd suggested that it represented remnants of a persistent ventral mesentery which failed to disappear normally and was drawn over the gut at the time of the latter's rotation.

SEVENTEENTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY*

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CONGENITAL CONDITIONS

Congenital Torticollis.—Feil [1] calls attention to the occasional fusion of the atlas with the occiput as both a primary cause of, and a contributing factor in, cases of congenital torticollis. In certain of his cases this fusion was present from birth, and in others it did not become apparent until about the age of 20. In two of his cases it was associated with the ordinary shortened sternomastoid and accounted for the slight deviation of the head which persisted after full operative correction of the muscular contraction had been accomplished.

Feil,[2] also, in another article, discusses the anatomy and clinical picture of six different types of malformation of the cervical vertebrae, which he illustrates by concrete examples.

Cervical Ribs.—A. S. Taylor [3] believes that the incidence of cervical ribs is about one in 300 persons and that the condition is usually bilateral. They vary in size from a complete rib down to a mere exaggeration of the transverse process. The symptoms are due to irritative pressure on the seventh or eighth cervical, or first dorsal, nerve, especially in those ribs that have a bladelike edge. Ribs with rounded borders are less likely to give important symptoms. He considers the treatment of these symptoms to be operative removal of the rib.

Trostler [4] has studied from a roentgenologic point of view sixty-five cases of cervical ribs. The diagnosis was correctly made clinically in only seventeen cases. In thirty-seven cases diagnoses such as neuritis or progressive muscular atrophy had been made, and in the remaining eleven cases the findings were incidental. There were more than twice as many females as males in the series. The symptoms were more

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* This report is based on a review of 524 articles selected from 627 titles having to do with the surgery of the extremities and spinal column, appearing in medical publications, chiefly between May 1, 1921, and Oct. 1, 1921. Only those articles have been chosen for comment which seem to represent progress in this branch of surgery.

1. Feil: Presse méd., Paris **29**:515 (June 29) 1921.
2. Feil: Progrès méd., Paris **36**:301 (June 25) 1921.
3. Taylor, A. S.: Cervical Ribs, J. A. M. A. **76**:1603 (June 4) 1921.
4. Trostler: Med. Rec. **100**:504 (Sept. 17) 1921.

frequent on the right than on the left side, and only nine persons showed symptoms on both sides. The average duration of symptoms was forty-five months. Of the thirteen patients operated on, all were partially or wholly relieved of the symptoms.

Pressure on the brachial plexus from costal elements has been discussed by Bramwell and Dykes.[5] They conclude that pressure symptoms may be caused by a cervical rib, by a rudimentary first dorsal rib, or by a normal first dorsal rib. They, as well as Trostler, find a much greater number of females than males affected. In twenty cases the average age of onset was 22 years. They believe faulty posture and, notably, confinement to bed are important etiologic factors. When the symptoms are not pronounced, attention to the general health, correction of posture, and temporary support of the arm by a sling may be expected to relieve the pain. When muscular weakness or atrophy produces constant annoyance, surgical intervention is indicated and is usually completely successful.

[ED. NOTE.—We have referred to this syndrome in earlier Reports of Progress and to the frequent failures of diagnosis, especially when no true cervical ribs are found to exist. Sir Harold Stiles has recently called attention to the common anatomic variations in the arrangement of the brachial plexus. There is the prefixed or high plexus, in which the first dorsal nerve may take no part, and the postfixed, or low plexus, into which the second dorsal nerve may enter. The neural elements embryonically are developed before the costal elements and influence the growth of these costal elements. The first rib is found in most of these symptomatic cases to be somewhat rotated and to show a deep groove for the first dorsal root. When removed and laid on a flat surface, it rocks instead of lying flat, as in the normal case. With a postfixed plexus and a rocking first rib, Sir Harold believes that the symptoms of irritation of the first dorsal root frequently occur. These symptoms are pain along the ulnar side of the arm, weakness in the muscles, chiefly of the ulnar distribution, and atrophy of the adductor and interossei of the thumb. The removal of the portion of the first rib over which the root passes has been successful in his cases. Undoubtedly, we should review with more care and understanding cases of persistent "neuritis" and arm weakness. The common onset of these symptoms in later life, although the anatomic variation has been of congenital origin, would suggest that correction of posture or change of occupation might be expected to relieve many patients. These cases, we believe, may well be confused with cases showing a degenerative or hypertrophic arthritis of the cervical spine. One would expect to find helpful differentiating evidence in involve-

5. Bramwell and Dykes: Edinburgh M. J. **27**:65 (Aug.) 1921.

ment of the sympathetic ganglion in these deeper changes, and changes in the pupil; but pupillary involvement does not occur in all the cases showing marked changes of a hypertrophic arthritic character, many of which are relieved by Thomas collars and physiotherapeutic and antiarthritic treatment.]

Congenital Malformations of the Vertebrae.—Spina Bifida: Crouzon and Béhague [6] have found bifid spinous processes in the dorsolumbar region in seventeen out of thirty-one patients. They believe that it is more common in tuberculous patients and has no connection with spina bifida occulta.

Léri and Engelhard [7] call attention to the frequency of anatomic variations of the vertebrae, most commonly the partial sacralization of the last lumbar vertebra in association with cases of scoliosis, spina bifida, "lumbago," "sciatica," and renal lithiasis. The lumbarization of the first sacral is rare but it is occasionally found.

An interesting and well written article has been published by Woltman.[8] The etiologic theories are discussed from Morgagni's article, in 1779, to Von Recklinghausen's, in 1886. Morgagni considered the condition due to a hydromyelia from overactivity of the choroid plexus, while von Recklinghausen believed that it was primarily due to a failure of the mesodermal envelop of bone and dura to approximate. He looked on the ectodermal dysontogenesis as secondary. Spina bifida and other anomalies have been experimentally produced. For example, Morgan and Tsuda [9] prevented closure of the blastophore by placing frog's eggs in a 0.6 per cent. solution of sodium chlorid, and Hertwig,[10] elaborating the method, actually produced permanent spina bifida. Stockard,[11] by use of solutions of magnesium chlorid, occasionally was able to bring about spina bifida in the common minnow (*Fundulus heteroclitus*). Moll [12] has noted that other malformations usually accompany spina bifida. Woltman [8] says that from experimental and clinical observations spina bifida cannot be explained on the basis of any single factor. There must be either some abnormal character of the gametes or mechanical, chemical, or physiochemical factors influencing the embryonic rudiments either before or after differentiation. The mechanistic action of accumulated cerebrospinal fluid, which Sharpe [13]

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6. Crouzon and Béhague: Bull. et mém. Soc. méd. d. hôp. de Paris **45**:403 (March 18) 1921.
7. Léri and Engelhard: Bull. et mém. Soc. méd. d. hôp. de Paris **45**:454 (April) 1921.
8. Woltman: Minnesota Med. **4**:244 (April) 1921.
9. Morgan and Tsuda: Quart. J. Micr. Sc. **25**: 1894.
10. Hertwig: Arch. f. mikr. Anat. **39**:1882.
11. Stockard: Anat. Rec. **3**:167, 1909.
12. Moll: J. Morphol. **29**:1906.
13. Sharpe: Ann. Surg. **61**:151, 1905.

considers from his experiments on dogs to be so important, Woltman believes could act only as a secondary cause. The findings in 187 cases are discussed. Twenty-four and six-tenths per cent. of these were of the occulta type. Hypertrichiasis, on the whole, is not common. Deformity of the foot, usually clubfoot, is one of the most common, and may be due to muscular weakness. Forty-nine patients over 5 years of age (excluding the occulta type) were studied. Eighty-four per cent. of this group showed evidence of cord involvement, and 71 per cent., sphincteric disturbances. There was motor paralysis in 53 per cent. and sensory changes in 45 per cent. Incontinence is common, and, while often not discovered early, becomes one of the most troublesome complaints. Of the fifty-seven patients operated on in the Mayo Clinic, twenty-two were cured, twenty-three improved, and twelve died. Two patients had postoperative hydrocephalus.

Christopher [14] has made a collective review of spina bifida occulta, quoting Wheeler's study of 1,000 roentgenograms of the lumbar region in which the incidence of incomplete closure of the posterior vertebral arches in the last lumbar vertebra was 2.3 per cent. The entire sacral canal was open in 2.89 per cent. of the entire series. After reviewing the experimental work on spina bifida, he considers the symptomatology. The cord may be normal or rendered abnormal by pressure or by reason of a false anlage, or by traction of the strand which connects the cord to the skin. Katzenstein,[15] however, has called attention to the fact that frequently the symptoms first appear between the ages of 9 and 17. He believes this may be explained by the fact that between these years the skeletal growth is at its maximum and consequently a maximum amount of pull is exerted on the cord by the band remaining adherent to the skin and passing through the adjacent bony structures.

The foot symptoms are variable, the commonest being talipes equinovarus; but equinovalgus and cavus occur. Paresis of the interossei has been reported by Guthrie,[16] and a chronic osteitis of the metatarsal bones by von Recklinghausen.[17] A very constant physical sign is the presence of one or two sacral dimples, commonly a small pit posterior to the anus. Cramer [18] says it is present in 40 per cent. of all infants; but if it has not disappeared by the tenth or twelfth year a spina bifida will usually be found.

The results from treatment have not been brilliant. Brickner [19] collected reports of twelve operative cases up to 1918 and added five of

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14. Christopher: Internat. Abst. Surg., p. 2, Supp. to Surg., Gynec. & Obst. **33**: July, 1921.
15. Katzenstein: Arch. f. klin. Chir. **64**:602, 1901.
16. Guthrie: Tr. Med. Soc. London **29**:399, 1895.
17. Von Recklinghausen: Deutsch. Ztschr. f. Chir. **18**:1, 1883.
18. Cramer: Ztschr. f. orthop. Chir. **32**:440, 1913.
19. Brickner: Am. J. Med. Sc. **155**:473 (April) 1918.

his own. There was no mortality, but rarely great improvement. He believes that one would be justified in operating on children without symptoms, in the hope of obviating later disturbances.

Katzenstein considers that the best chance for a good operative result would be furnished by those cases showing first symptoms in early youth or at puberty.

Chute [20] reports four cases of retention apparently due to disturbance of the normal innervation of the bladder. A spina bifida occulta was discovered in all four cases. These symptoms of retention occurred in adult life, from 22 to 35 years in the reported cases. He thinks the late occurrence is due to the unequal growth of the canal and the cord and to the gradual traction on the nerves by the membrana reuniens. Chute states that freeing these sacral nerves has in some cases brought remarkable results and that the danger of the operation is slight.

[ED. NOTE.—It is well to have our attention directed to this rather obscure condition of spina bifida occulta and to realize that it may be the cause of serious progressive symptoms and deformities. Its possible existence must not be forgotten, especially in slowly developing contractures and paralysis of the lower leg muscles in which no other etiologic factor appears. Operative interference, to have any chance of success, must apparently be early and the prognosis is doubtful even then. We must also remember that the condition exists in a large number of persons who show no symptoms which can be attributed to it. It is a very frequent finding in roentgenograms of the low spine which have been made for various purposes.]

Congenital Dislocation of the Hip.—Ridlon [21] records 437 personally observed cases of congenital dislocation of the hip. Eighty-seven per cent. were in females and 13 per cent. in males. Seventy-one per cent. of the cases were unilateral.

The report of the commission appointed by the American Orthopedic Association to study the end-results of congenital dislocation of the hip is important.[22] The commission was made up of Dr. J. E. Goldthwait, chairman, Dr. Z. B. Adams, and Dr. DeForest P. Willard. The commission decided that three years must have elapsed since operation in order that the then existent condition be considered a true end-result. The number of cases in which records were available for study proved to be very small compared to the number of patients treated. The records of the New York Orthopedic Dispensary and Hospital were the best. In general, it may be said that from the

20. Chute: J. Urology **5**:317 (April) 1921.

21. Ridlon: J. Orthop. Surg. **3**:365 (Aug.) 1921.

22. Goldthwait: J. Orthop. Surg. **3**:353 (Aug.) 1921. Adams: Ibid. **3**:357 (Aug.) 1921.

material available it was evident that few hips were normal in their bony form either before or after treatment. An anatomically normal hip was rarely seen. There was no suggestion that these changes were due to rickets. From the point of view of function, many cases were entirely satisfactory. Certain points in the anatomic structure were suggested as influencing the possibility of replacement and the permanence of the result. These were the obliquity of the innominate bones, the axis of the neck vertically and anteroposteriorly, and the inclination of the epiphyseal cartilage. From the results observed, it is evident that the very least possible violence should be employed in whatever form of reduction is used, since the capital epiphysis may be easily damaged, with resulting serious interference with its development. The commission makes a strong plea for better records as to the details of the reduction and the after-care. Next in interest to the great number of marked changes in the shape of the capital epiphysis in successfully reduced and, often well functioning, cases were the statistics as to the older cases. The cases of forty-six patients who were 6 years of age or older when the reduction was attempted were studied. On the forty-six patients, in fourteen of whom the condition was double, seventy attempts at reduction had been made. Twenty-four hips remained in; twenty-nine did not; one result is questionable, and six are marginal. Of the double cases, four reductions were attempted by the machine methods; three of these patients have one hip in and one out. One has both hips in; but the head of one of the bones has almost disappeared. Of three patients manipulated on the Hibbs' table, one patient has both hips in and has fair function; one double case is questionable on both sides, and the third patient has one hip in and one is questionable. One of Dr. Stern's eleven patients has both hips in and good function. Of the remaining six double cases, one patient has one hip in and one is questionable, and five patients have both hips out. The statistics for these older double cases studied are surely not very favorable. They are better, obviously, in the older single hip cases. The classical Trendelenburg sign was found still present in certain of the anatomically reduced hips in which the glutei were weak, and it was not always present in cases in which there existed a true dislocation. It is, therefore, not an entirely dependable diagnostic sign.

Léri [23] has studied an hitherto undescribed familial disease to which he gives the name pleonostosis familiale, because of the epiphyseal overgrowth and premature ossification. The condition is a skeletal dystrophy present in a father, aged 30, a daughter, aged 4 years, and a son, aged 3 months. It is most evident in the father and least evident in the son, but the condition is pronounced, definite, and exact in each. The hands are short and broad and the fingers very large; the arms are

23. Léri: Bull. et mém. Soc. méd. d. hôp. de Paris **45**:1228 (July 29) 1921.

bowed, and all joint motions in the upper and lower extremities are limited. The neck is short and thick, but the head itself is normal. The roentgenograms show precocious bony growth in thickness, especially in the diaphysis and at the joints of epiphyseal growth. The thickened epiphysis limits motion and causes a premature disappearance of the cartilage.

Renal Dwarfism.—Barber [24] describes a form of interstitial nephritis in children which gives rise to dwarfism and bony deformities. Only five postmortems have been obtained; but the findings have been similar in type, varying only in degree. The kidneys are very small. Although the children have been considered a little under sized since birth, the condition is not very noticeable until about 6 or 7 years, after which the stunted growth becomes striking. Bone deformities, especially genu valgum, have been present in eight of the ten cases. Steady progression of the disease has been the rule, with a fatal termination usually in the second decade. No treatment has been found to affect the condition.

TUBERCULOSIS

Tuberculosis of Bone.—In an article reporting a microscopic study of specimens from fifty cases of bone tuberculosis, Allison [25] discusses the variety of lesions observed in bones and neighboring tissues which result from one infective agent, the tubercle bacillus. The different character of these lesions Allison believes is due to the different reaction of different tissues. No instance in his series suggested primary synovial tuberculosis, the bone being the focus from which it extended in every case. He further states: "In all instances in this study in which tuberculous bone lesions were observed there was both bone destruction and bone proliferation. When cancellous bone was involved, destruction predominated. When compact bone was involved, proliferation predominated." Allison concludes that the classification of tuberculous lesions as observed in the different tissues should be much simplified. He believes that all of the various changes observed are only the natural and usual reactions to infection of the special tissue involved. Certain of these tissues have the quality of quickly reacting to stimulation with proliferation, while others show little or no tendency thus to react, and suffer destruction.

Cole,[26] in a paper read before the Mississippi Valley Conference on Tuberculosis, considers that pure diaphyseal bone tuberculosis without joint involvement is extremely rare in this country. He also cites the findings of tubercle bacilli in the mesenteric glands of stillborn infants as proof of the possibility of true hereditary or congenital infection.

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24. Barber: Quart. J. Med. **14**:205 (April) 1921.
25. Allison, Nathaniel: Tuberculosis of Bone, Arch. Surg. **2**:593 (May) 1921.
26. Cole: Minnesota Med. **4**:228 (April) 1921.

[Ed. Note.—The Editors have no microscopic evidence which justifies them in differing from the conclusions of Allison. His careful work is a confirmation of the earlier work of Nichols,[27] who also reached the conclusion that all joint tuberculosis was primary in the bone. It is well to remember, however, that John Fraser[28] and the Edinburgh school hold that synovial tuberculosis, especially of the bovine type, is often primary; and they have certain microscopic evidence to substantiate their claim. Clinically and roentgenologically, of course, the evidence strongly suggests, but does not scientifically prove, that the primary synovial form does occur, and we see no reason why it should not occur if primary pleural and peritoneal and tenosynovial tuberculosis is admitted. It is fair to conclude, however, that joint tuberculosis most commonly originates in the bone, and that the diagnosis of purely synovial tuberculosis must be made with great caution. We are inclined not to agree with Cole that diaphyseal tuberculosis without joint involvement is so rare in this country as to be negligible. In the series of bone lesions studied clinically, roentgenologically, and pathologically by Lovett and Wolbach,[29] there were several proved cases of diaphyseal tuberculosis without joint involvement, and in the type of dactylitis called spina ventosa the involvement is almost wholly diaphyseal.]

Serologic Tests in Surgical Tuberculosis.—Fried and Mozer[30] believe that incipient syphilis and tuberculosis may be detected by serologic tests long before they are clinically manifest. In sixty-eight tuberculous children the tests were positive in more than 70 per cent. when the known tuberculous process in the spine, hip, or knee was of less than three years' duration, but in only about 30 per cent. when it had existed longer than this. In grave cases with fistulas the reaction existed less frequently. In 165 children with rickets the percentage of reaction was only 7.5.

Tuberculous Spondylitis.—Treves[31] pleads for the treatment of Pott's disease in recumbency and by heliotherapy, but without the employment of plaster jackets. These he believes prevent chest expansion, cause atrophy of the back and body muscles, and actually lessen the efficacy of recumbency.

[Ed. Note.—Fixed and irremovable jackets we also believe are of no advantage in recumbency, but the use of plaster posterior shells or of fixation on a Bradford frame in hyperextension would seem to

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27. Nichols: Boston M. & S. J. **141**: Jan. 27, 1898.

28. Fraser, John: Tuberculosis of Bones and Joints in Children, New York, The Macmillan Company, 1914.

29. Lovett and Wolbach: Surg., Gynec. & Obst. **31**:111 (Aug.) 1920.

30. Fried and Mozer: Presse méd. **29**:436 (June 1) 1921.

31. Treves: Bull. méd. **35**:197 (March) 1921.

offer a wise restraint to the activity of most children, even in bed. This apparatus may be removed several times a day if desirable for massage and even light muscular exercise, and in no way does it diminish the power or range of chest expansion.]

Of a series of 2,790 cases of osteo-articular tuberculosis treated from 1899 to 1919 at the Rizzoli Institute, 1,271 were of the spine, forming 45.5 per cent. Valtancoli [32] reports the result of a study of 1,004 cases of tuberculous spondylitis treated at the Institute from 1907 to 1919. Of these, 47.2 per cent. were males and 52.8 per cent. females. The statistics show the disease is one of the first thirty years of life; also that for the first fifteen years it attacks males and females equally; that from 15 to 45 years it attacks females more frequently, and after 45 males more frequently. The greatest number of cases occur between 3 and 5 years of age, the larger number occurring at 4 years. Thirteen per cent. showed a tuberculous heredity; 7.3 per cent. gave a history of a definite preceding trauma; 21 per cent. had had pleurisy previously; 19.7 per cent. had a concomitant tuberculosis elsewhere. The localization of the spondylitis follows: suboccipital, 1.5 per cent.; cervical, 7.8 per cent.; cervicodorsal, 2.8 per cent.; dorsal, 40.8 per cent.; dorsolumbar, 16.2 per cent.; lumbar, 31 per cent.; lumbosacral, 1.2 per cent.; sacral, 0.4 per cent. Abscesses occurred in 26.6 per cent. It is interesting that in 39.2 per cent. of the cases with abscesses no kyphosis was present. Symptoms were distributed thus: 75.6 per cent. had pain; 73.3 per cent., rigidity; 68.6 per cent., deformity; 18.7 per cent., scoliosis, and 3.9 per cent., paraplegia. Results of cases followed from one to five years were: good, 41 per cent.; fair, 25.4 per cent.; stationary, 13.1 per cent.; bad, 8.7 per cent.; dead, 11.6 per cent. Results of cases followed for fifteen years were: good, 68.6 per cent.; fair, 11.1 per cent.; stationary, 3 per cent.; bad, 1.5 per cent.; dead, 15.1 per cent. The mortality in 612 cases followed was 16.5 per cent.

Tuberculous Coxitis.—Vacchelli [33] presents a statistical study of tuberculosis of the hip occurring at the Instituto Ortopedico Rizzoli. Of 2,790 cases of osteo-articular tuberculosis, treated from 1899 to 1919, 26.9 per cent. were of the hip. Of his series of 506 treated from 1907 to 1919, 52 per cent. were males and 48 per cent. females. The right hip showed 52.8 per cent.; the left, 45.9 per cent., and both, 1.3 per cent. It is chiefly a disease of the first eighteen years of life, and occurs especially in the second three years of life. In 29.6 per cent. of the cases there was a history of tuberculosis in a near relative; in 16 per cent. of the cases there was a history of a recent trauma; in 28 per cent. of the cases there was a history of a previous concomitant tuberculous lesion elsewhere.

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32. Valtancoli: Chir. d. org. di movimento. **5**:127 (April) 1921.
33. Vacchelli: Chir. d. org. di movimento. **5**:159 (April) 1921.

Pain was the first symptom in a majority of the cases and a limp was almost as common. Limitation of motion is almost always present. Some abnormal position was present in about three fourths of the cases. Shortening was present on admission in 36.3 per cent., and lengthening in two cases. There were twenty-eight cases of luxation in the series of 506 cases. Abscesses occurred in 40.5 per cent.

Roentgenographic studies showed diffuse lesions (synovial?) in 52 cases; isolated foci in 122, of which 60 were in the femoral head, 24 in the neck, 30 in the acetabulum, and 8 in the trochanter. Diffuse foci of the head and acetabulum were present in 220.

In the vast majority of cases treatment was nonoperative. In early cases or in those with active symptoms, rest in bed with traction was employed. In late cases, immobilization, usually with plaster-of-Paris casts, was used. In case the lesion was in the upper part of the head or in the roof of the acetabulum, a metal staff was inserted in the cast, which extended below the foot, so that the weight came on it and with counterpressure on the tuber ischii. Researches of Sangiorgi at the Rizzoli Institute have demonstrated that bone destruction and shortening in severe cases of tuberculous coxitis, involving the superior part of the head or the roof of the acetabulum, and in the synovial forms with marked bone atrophy, are much greater in patients in whom weight bearing is allowed than in those in whom it is prevented. Forcible correction of deformities has been given up. Heliotherapy has been used only a little, but this is due only to lack of opportunity. Abscesses are treated if possible by aspiration, repeated as needed. Glycerin with iodoform has been used for injections into abscesses with some success. In the case of fistulas, the use of Beck's paste has been given up. Heliotherapy offers the best results. The author states that operative treatment of tuberculous coxitis as such has been given up at the Rizzoli Institute, as conservative treatment gives better results. Subtrochanteric osteotomy was performed in forty-two cases, with good results in thirty-nine, and with recurrence of the deformity in three. Duration of the treatment varied from a minimum of one year to a maximum of twelve, with an average of from three to four years. Experience has taught that it is wise to maintain fixation for a long period after the disappearance of every symptom of an acute process. Four hundred questionnaires were sent to patients and 276 replies were received. Of those replying, forty-nine had pain; twenty-two had fistulas; 170 had shortening; 155 had rigidity (total); fifty-six had partial fixation; 196 had a limp; twenty-nine were dead. Of the 276 studied, as last seen, the results were classified as follows: excellent, 11.2 per cent.; good, 62.6 per cent.; fair, 13.7 per cent.; unchanged, 2.1 per cent.; dead, 13 per cent.

Tuberculosis of the Knee Joint.—Sacco [34] reports 402 cases of tuberculosis of the knee treated at the Rizzoli Institute from 1907 to 1920. Two hundred and thirty-seven (58.18 per cent.) were males, 165 (41.21 per cent.) were females. The right knee was involved slightly more frequently in men and the left knee in women. In only about 6 per cent. was there an hereditary taint. It is a disease of the first thirty-five years. Trauma played only a small part as a predisposing cause. Pleurisy as a direct precursor had a considerable rôle (10 per cent. of the cases).

The picture was usually of a swollen knee, with the leg flexed on the thigh, subluxated, and in external rotation. Diagnosis was made from the clinical picture, roentgenograms and focal tuberculin reaction. The pathologic picture is drawn from sixty-nine resections, of which thirty-seven showed the disease largely in the bone, thirteen in the synovia, eight in both bone and synovia, and various changes in the other cases. Fistulas developed in fifty-three cases. Deformity of the knee occurred in 145 cases. Two hundred and twenty cases were treated by immobilization, while in 182 some form of surgical intervention was used, sixty-nine typical resections and forty so-called economic operations, such as supracondylar osteotomies, curvilinear osteotomies, and cuneiform resections. Of the sixty-nine typical resections, forty-one gave excellent results. Of the forty so-called economic operations, thirty-seven gave excellent results. Of the 220 cases treated by immobilization, 138 cases indicated that the results would be good, while eighty-two were still under observation. Final end-results were not given.

Tuberculosis of the Foot.—Cicconardi [35] reports 145 cases. The article cannot, as a whole, be abstracted. Two methods of treatment were used. So-called conservative treatment in which immobilization was the most important feature was used in 112 cases. Operative treatment was employed in thirty-three cases. Of the 112 patients, thirteen were cured, forty-five improved, twenty-two were still under treatment, twenty-nine were discharged unimproved, one was unknown, one was worse, and one was dead of another cause. Of the thirty-three cases in which operation was performed, fourteen patients were cured, six were improved, four had had amputation and were cured, the results in two were unknown, two were under treatment, four were worse, and one was dead of another cause.

Referred Pains of Spondylitis.—Ramond and Jacquelin [36] and Marchal [37] emphasize the importance of referred pain and tendon

34. Sacco: Chir. d. org. di movimento. **5**:193 (April) 1921.
35. Cicconardi: Chir. d. org. di movimento. **5**:209 (April) 1921.
36. Ramond and Jacquelin: Prog. méd. **36**:155 (April 9) 1921.
37. Marchal: Arch. méd belges **74**:206 (March) 1921.

reflexes in syphilitic and tuberculous disease of the vertebrae. Arm and chest pain may be the only signs in the upper regions, while epigastric pain and gastric crises may be caused by a radiculitis and the irritation of the splanchnic nerves at the seat of the spinal lesion. These referred pains have long been recognized in spinal lesions; but the authors do well to point out the fact that they may entirely obscure the local vertebral signs and may simulate very closely those of a gastric or duodenal ulcer or gastritis. Food often brings on the acute symptoms, but sodium bicarbonate gives no relief.

Guillain and Laroche [38] have observed such severe symptoms following lumbar puncture in several cases of vertebral caries that they believe the method should be used with great caution as a diagnostic measure in probable Pott's disease. Paralysis of the legs occurred in several cases.

Hypertrophic Osteo-Arthropathy in Pulmonary Tuberculosis.—Corper, Cosman, Gilmore, and Black [39] have examined the hands and feet of 102 patients with pulmonary tuberculosis under treatment in a Denver hospital. There is found a high percentage of convex nails, regardless of the stage of the disease, and a transverse ridging is more common and marked than in normal persons. Hypertrophy of the soft tissues at the tips of the fingers and toes, which is rarely found in so-called normal persons, is common in the consumptive. Bone hypertrophy seen at the tips of the distal phalanges and as periosteal thickening of the shafts of the phalanges and metacarpals and tarsals, may occasionally be found in so-called normal persons; but it is common to a pronounced degree in active cases of pulmonary tuberculosis.

SYPHILIS

Experimental Syphilis in Rabbits.—Brown, Pearce, and Witherbee [40] have been studying the affections of bone, cartilage, tendons, and synovial membranes in rabbits experimentally inoculated with suitable strains of *Spirochaeta pallida*. It was found that syphilis of the skeletal system of rabbits was a very characteristic thing and might combine features of both the acquired and the inherited form in man. The conditions are not identical, but contain many fundamental characteristics, thereby affording, in the experimental form, opportunities for the study of lesions of the skeletal system. The parts of the animal involved, in order of their frequency, were the facial and cranial bones and cartilages, the feet and leg bones, the tendons and joints, the

38. Guillain and Laroche: Bull. et mém. Soc. méd. d. hôp. de Paris **45**:794 (May 27) 1921.

39. Corper, Cosman, Gilmore and Black: Am. Rev. Tuberculosis **5**:357 (July) 1921.

40. Brown, Pearce and Witherbee: J. Exper. Med. **33**:495 (April) 1921.

cervical and caudal vertebrae, the ribs and the sternum. Clinical manifestations were often present; but at times the changes could only be detected roentgenologically or pathologically. Three aspects of this experimental study are significant: (1) the analogy between certain forms of the animal and human infections; (2) the relation of syphilis of the osseous system to other evidences of the disease, and (3) the frequent occurrence of obscure bone lesions.

Klauder,[41] reporting five cases of "backache" due to syphilis, concludes that in the majority of cases it is a symptom of spinal cord affection. Backache, stiffness, and general tiredness are the chief complaints. A plea is made for a careful history and physical examination of every syphilitic patient in order that treatment may be administered in the meningeal stage of neurosyphilis instead of in the late parenchymatous stage.

Finck [42] reports a case of arthritis deformans which he believes was attributable to a syphilitic involvement of the thyroid and parathyroids in a woman of 46 years.

Eloesser [43] believes that the occasionally encountered painful tabetic fracture or Charcot joint may be explained by the fact that while a true and complete analgesia of the bone exists in these cases, the skin and soft parts still retain their sensibility, and that the pain is due to the distention of these soft part structures. This dissociation of bone and skin pain sense may well indicate that the pain fibers for these different tissues run in different paths in the spinal cord.

PARALYSIS

Nerve Injuries Due to Birth Trauma.—Friedman,[44] in a series of 2,000 consecutive neurologic cases examined at the Children's Hospital in Boston, found 101 cases of obstetric paralysis the cause of which was definite trauma during labor. There were sixty-three cases of spastic paralysis, sixty cases of feeblemindedness, and twenty-four miscellaneous cases in which birth injury seemed to Friedman to be the probable cause. He believes that thirteen per cent. would be a conservative estimate to attribute to this cause in the series studied. None of the doubtful cases were included.

Surgical Treatment of Brachial Plexus Injuries.—Adson [45] has studied 101 cases of brachial plexus injuries recorded in the Mayo Clinic since 1910. Forty-five of these were birth palsies; and in all but

41. Klauder: Arch. Dermat. & Syph. **3**:761 (June) 1921.
42. Finck: Bull. méd. **35**:466 (June 4) 1921.
43. Eloesser, Leo: Sign Occurring in Cases of Tabes Complicated by Charcot Joints, J. A. M. A. **77**:604 (Aug. 30) 1921.
44. Friedman: Boston M. & S. J. **184**:482 (May 12) 1921.
45. Adson: New York State J. Med. **21**:331 (Sept.) 1921.

five there was a history of a difficult or operative delivery. Dislocations of the shoulder were noted in thirteen cases; but the incidence of this condition was much greater in the age group above 2 years, from which he argues that Turner Thomas's theory of primary shoulder dislocation with laceration of the capsule and resultant axillary inflammation as the etiology of the lesion is not borne out. Treatment (presumably nonoperative) was attended by great improvement in function, especially in the early cases. Fifty-six cases of traumatic brachial paralysis were studied; twenty-three of these were produced by trauma to the shoulder and neck without fracture; twelve were associated with fracture or dislocation of the humerus or clavicle; thirteen were caused by belt injuries; eight by gunshot or stab wounds. Twenty-five of these patients were operated on; and exploration of the plexus usually revealed laceration of the nerve roots close to the intervertebral canal, with such wide involvement in scar tissue that it was only rarely possible to resect and anastomose. Fourteen of the twenty-five operations were failures. Eleven patients were improved to approximately 40 per cent. of function. Thirty-one of the patients were treated without operation, and only four showed little or no improvement. Twenty-six regained at least 45 per cent. of function. Failure, therefore, resulted in 58 per cent. of the cases in which operation was performed and in 15 per cent. of the cases in which operation was not performed. Adson also presents a preliminary report on experimental tears of the brachial plexus produced on cadavers soon after death. He concludes that while production of complete laceration or avulsion is difficult, it is possible, and, depending on the manner in which the force is applied, may affect the upper or lower portion of the plexus with avulsion of the sympathetic ganglion. Owing to the proximity of these lacerations to the intervertebral canal, operative repair is very difficult. He believes that many of the brachial palsies are due to lacerations of the cervical fascia, epineurium, perineurium, fasciculi, and blood vessels, rather than to complete tears or avulsions of the nerve cords themselves.

Maragliano,[46] after discussing the various theories of etiology of obstetric paralysis, concludes that the usual cause is injury to the plexus. The treatment which he has employed of fixing the arm in abduction, external rotation, flexion of the elbow, and extension of the wrist and fingers has been most successful.

Poliomyelitis.—Peabody [47] reports the results of the study, by the Harvard Infantile Paralysis Commission, of the treatment of poliomyelitis by serum injection in the epidemics of 1916 and 1920. In forty-three cases in which the diagnosis was confirmed by lumbar puncture, but in which no serum was employed, 65 per cent. did not develop any

46. Maragliano: Chir. d. org. di movimento **5**:32 (Feb.) 1921.
47. Peabody: Boston M. & S. J. **185**:174 (Aug. 11) 1921.

paralysis. Reviewing the cases treated with serum, and similar groups reported by Draper, Amoss, Zingher, Rosenow, and others, we find that the percentage of cases not developing paralysis is about the same. More prolonged study of the nature of the disease must be awaited before anything more definite as regards treatment by serum can be offered.

Rosenow [48] feels more hopeful concerning the results of treatment by means of his immune horse serum prepared by repeated injections of increasing doses of freshly isolated strains of pleomorphic streptococci. The favorable results were in general proportionate to the earliness of the injection. When improvement occurred it was with such regularity and of so marked a degree in the early cases that Rosenow believes that accidental occurrence can be excluded. The absence of death, the low incidence of paralysis, and the almost total absence of residual paralysis are attributed by him to the early administration of the serum. The early diagnosis must be made by spinal puncture in all suspicious cases. Rosenow noted improvement in clinical symptoms, but does not seem to show any marked reduction in the percentage of paralytic cases.

Levine,[49] as a result of work with the Harvard Infantile Paralysis Commission, states that there is no difficulty in making a diagnosis of poliomyelitis when definite paralysis has set in. The early diagnosis before this occurrence is, however, most to be desired. He believes, as a result of a large experience, that stiffness of the neck, with a slight fever, is a seriously suspicious sign. The only other diagnostic measure of value in the incipient cases is lumbar puncture. As a therapeutic measure it is of little value, though there may be slight relief due to the lessening of pressure. A normal cell count practically rules out poliomyelitis. A clear fluid with an increased number of cells is characteristic of poliomyelitis. Tuberculous meningitis, cerebral syphilis, and epidemic (lethargic) encephalitis show a similar fluid, but exhibit other symptoms which usually readily differentiate them.

The Surgery of Poliomyelitis.—Teece [50] believes that the mechanical aspects of tendon transplantation have obscured the physiologic aspect. The fundamental essentials are a thorough understanding of the function and action of individual muscles, an accurate determination of the muscles that are paralyzed and their possibilities of recovery, and a knowledge of the methods of encouraging recovery by reeducation. He makes the following points: (1) Muscle training before operation is important. Contraction, relaxation, isolated individual action, and

48. Rosenow, E. C.: Treatment of Acute Poliomyelitis with Immune Horse Serum, J. A. M. A. **77**:588 (Aug. 20) 1921.

49. Levine: Boston M. & S. J. **185**:238 (Aug. 25) 1921.

50. Teece: J. Orthop. Surg. **3**:405 (Aug.) 1921.

dissociation should be mastered. (2) Bony deformity must be corrected before transplantation operations. (3) Synergists should be favored for transplantation. (4) Transplantations of a complex nature should be avoided. (5) In extensive paralysis it may be advisable to perform an arthrodesis of one or more proximal joints before transplantations are undertaken for the peripheral portions of the limb. (6) The gliding mechanism must be preserved if possible. (7) The tendons must be sutured under adequate tension.

Rugh [51] reviews the history of surgery in its attempts to correct the deformities of poliomyelitis. The tenotomy of Stromeyer in 1831, the arthrodesis of Albert in 1878, and the astragalectomy of Whitman, he considers the only methods which have survived unchanged. He believes that the use of silk and fascia as ligaments has failed. Only simple tendon transplantations are advocated. Muscle intelligence and muscle sense must be acquired before the transplanted muscle can fulfil its new function.

Hannah [52] reports an unusual type of acute infantile paralysis. There was absence of fever, headache, pain, and convulsions, and the presence of a hemiplegic type of paralysis with facial involvement.

[ED. NOTE.—A few similar cases have come under the Editors' cognizance during severe epidemics of poliomyelitis.]

Report of Commission on Stabilizing Operations for the Foot in Cases of Poliomyelitis.—The Commission appointed by the American Orthopedic Association to review the results of the different stabilizing operations for paralytic deformities of the foot made the following report (A. G. Cook, chairman, and W. G. Stern [53]): 1. The use of metal plates, wires, screws, nails, etc., silk ligatures, and bone grafts is objectionable or unreliable. 2. Excellent results in cases of lateral instability have been obtained by arthrodesis. The best results may be expected to follow the triple arthrodesis of Ryerson or the sub-astragaloid arthrodesis of Davis. Arthrodesis of the ankle joint is rarely indicated. 3. Astragalectomy with backward displacement of the foot after the method of Whitman, first for calcaneovalgus, second, for dangle feet, third, for lateral deformity, gives by far the best results. 4. Horizontal transverse tarsectomy after the method of Davis gives by and large less perfect results than astragalectomy and is a more difficult, bloody, and less surgical procedure. 5. The use of living ligaments after the methods of Gallie, Putti, Peckham, and others has afforded isolated successes, but as a general rule has not been satisfactory. 6. Failures following tendon transplantation were common, and the commission believes that the main use of tendon transplantation is as an adjuvant to a stabilizing operation.

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51. Rugh: Ann. Surg. **74**:61 (July) 1921.
52. Hannah: Med. Rec. **100**:364 (Aug. 27) 1921.
53. Stern: J. Orthop. Surg. **3**:444 (Sept.) 1921.

[ED. NOTE.—The commission has been continued, and it is hoped that it will report subsequently on the skeletal adjustments of Hoke of Atlanta, which seem to the Editors to show such excellent results and to be so nicely conceived and executed. They would seem to be less deforming and less likely to interfere with growth than other bony operations, and to furnish excellent stability. It is to be hoped also that the commission will further review the work of Gallie with living sutures and ligaments. The Editors have observed Gallie's own results, and the success is so much greater than the results of the method in other surgeons' hands that it seems possible that other men have perhaps not mastered Gallie's own technic and that the method may yet prove of great value in selected cases.]

Paralysis in Children Due to the Bite of the Wood-Tick.—McCornack,[54] in 1903, first reported finding a large wood-tick in the skin at the base of the spine of a woman, aged 22, suffering from motor paralysis. The removal of the tick was followed by the rapid disappearance of the paralysis. In the last ten years, McCornack has observed ten more cases of paralysis in children associated with bites of the wood-tick *(Derniacentor venustus)*, which is also responsible for Rocky Mountain spotted fever. Paralysis in sheep due to the wood-tick has been reported from Cape Colony. Hadwen, in 1913, succeeded in producing paralysis in animals experimentally from bites of the wood-tick. It has been impossible to reproduce the disease by inoculation. Experimentally incubation seems to require about eight days in the lamb. Improvement began soon after the onset of the paralysis, and complete recovery usually occurred from the twelfth to the sixteenth day. One attack seems to confer a lasting immunity. The sudden onset may be accompanied by convulsions, rapid pulse, and slight rise in temperature. There is weakness in the muscles of the extremities, staggering, and disinclination to play, followed in a few hours by more or less complete motor paralysis. Consciousness is not impaired. A large engorged wood-tick is found somewhere on the body, in the axilla, ear, temporal region, occiput, and other places. The recovery is usually complete and rapid, following the removal of the tick. Occasionally, when the tick is not removed, death results from respiratory failure. The diagnosis may readily be confused with poliomyeltis and depends on finding the tick, usually in the hairy scalp or other protected places. The only case in the author's series in which a complete blood examination was made showed an eosinophilia. In removing the tick much care must be exercised in removing the head. Gentle traction usually suffices. It may be covered with grease and as it moves to breathe it can be picked off. These symptoms by no means always supervene on the bite of wood-ticks.

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54. McCornack, P. D.: Paralysis in Children Due to Bite of Wood-Ticks, J. A. M. A. **77**:260 (July 23) 1921.

[ED. NOTE.—If the bite of the wood-tick has been definitely proved to cause a type of motor paralysis without any cerebral disturbance, it seems to us that it should greatly stimulate the further search for some agent, especially some insect agent, which may be responsible for the epidemics and sporadic cases of poliomyelitis. The wood-tick paralysis is usually transitory, but, according to the Harvard Commission, in 65 per cent. of the undoubted cases of poliomyelitis the patients recover without permanent paralysis. According to McCornack, the wood-tick paralysis may go on to respiratory paralysis and death in certain cases if the tick is not removed. Again the analogy is suggestive. The mud hornet, according to Shurtleff (private communication), makes sure that its hatching larvae shall have fresh meat by stinging a spider, which becomes completely paralyzed. He is placed by the thoughtful parent at the bottom of the larvae's mud hole and there he continues to live, unable to escape until the hatching larvae are ready to devour him. There is much to suggest other than human carriers of poliomyelitis. An epidermiologist and an entomologist might perhaps be very helpful partners in such a search.]

ARTHRITIS

Pemberton [55] has published another excellent article on the subject of arthritis. It is limited to a statement of the principles on which the dietary treatment rests and is replete with words of caution against the indiscriminate use of this method, which will end by bringing it into disrepute without real trial. The observations on which the dietary treatment is based are certain altered metabolic factors seen in arthritis. These are chiefly a high blood creatin, which tends to disappear as the patients improve, and a lowered sugar tolerance, which occurs in direct relation to the severity of the arthritis and grows less or disappears as convalescence proceeds. The lowered sugar tolerance is not specific for arthritis and should be interpreted only as reflecting part of the underlying pathology of this disease, which from experimental studies apparently consists in an interference with the respiratory functions of the circulatory blood. The sugar tolerance returns to normal most abruptly after the removal of causative foci of infection. Dietary restrictions cater to this weakened function, probably an oxidative function, dislocated in most cases by some inflammatory process, usually in the form of focal infection. Following on a chronic focus of infection, however, there may be a more or less permanent dislocation of normal physiology, as illustrated by the lowered sugar tolerance, such that removal of the focus is not sufficient to restore it; and this explains the frequent disappointing results following eradication. A preponderating number of patients with chronic arthritis, if placed on a

55. Pemberton: Am. J. M. Sc. **161**:517 (April) 1921.

sharply reduced intake of food or on a starvation basis, will show, within a period of from one to four days, an improvement. This may occur even in the presence of causative foci of infection; but it is evidently a mistake to use this therapy in the presence of such removable infection. Its use should not be attempted except after thorough search for and eradication of these. Before beginning dietary treatment it is advisable to determine over a period of from seven to ten days, under conditions approximating the average life of the person, the accustomed food intake in terms of calories. It is also useful to know the percentage distribution of calories in fat, protein, and carbohydrate, because of the indications that it is the latter that is the chief offender by virtue of its quick combustion and the large rôle it assumes in average dietaries. Dietary restriction must be determined for each individual case. No generalization is possible. Treatment must be carried to the point where the patient is spared the necessity of metabolizing as much food as he had been previously ingesting. When patients are suffering from chronic malnutrition, a lowering of the caloric content is attended by danger, and it must be remembered that in itself arthritis is not a fatal disease.

No rule can be advanced for any given case; but the nearest approach to such help is based on the recognized approximate requirement of 30 calories per kilogram of body weight under resting conditions. This may not achieve a result in all cases; but with this as a basis, other forms of therapy, such as massage, which were formerly inoperative, may now become operative. Sometimes a period of absolute fasting will demonstrate dramatic results; but it is too dangerous to be generally advised. In the early stages of a sharply restricted diet there may be a rapid loss in weight. Under these conditions there may be marked improvement due to the fact that catabolism is running ahead of anabolism. Later equilibrium is established, and improvement may cease, or even an exacerbation may occur. It is at this time that the test of the applicability of the diet comes and other measures may be required. When convalescence is thoroughly established, an increased caloric intake is often possible, sometimes to such a degree that the individual can resume his previous activities with even added efficiency.

Nonspecific Therapy.—Betz [56] reports the treatment of fifty cases of arthritis by injections of nonspecific protein. The typhoid vaccine was employed in all but two cases, in which gonococcus was substituted. Nearly all the acute cases cleared up after one injection. In two cases three injections were necessary. Ninety per cent. of the subacute cases cleared up after one or more injections. In the chronic cases with marked ankylosing tendencies a moderate improvement was the rule.

56. Betz: Med. Rec. **99**:920 (May 28) 1921.

The contraindications are that in alcoholic patients, delirium may be caused, and in pregnant women there is danger of abortion. High blood pressure is also a contraindication as is also a history of anaphylaxis. The average dosage is 250 million. Larger doses make the reaction uncertain, if not dangerous. There was no evidence to suggest that intravenous injections had any untoward effect on the heart or kidneys. In the series mentioned above Betz states that other forms of treatment have been tried and found unavailing.

[ED. NOTE.—Our personal experience in the past in a few cases of the more chronic type has not been encouraging. The conflicting reports and the temporary discomfort to the patients would seem to emphasize the necessity of further careful work before any general employment of the method is undertaken.]

Influenzal Arthritis.—Roello [57] reports two cases of purulent arthritis in infants following influenza, one in the shoulder joint in an infant of 13 months, and one in the hip of a child of 3 years. The shoulder was opened early and pus containing typical lanceolate gram-positive diplococci was found. Perfect motion was obtained eventually. The hip joint was not operated on early, but discharged of itself. A redislocation occurred and acetabular changes made it impossible to reduce it. Early arthrotomy in suppurative joints of this etiology would seem advisable.

Gonococcal Arthritis.—After a careful study of 100 cases of gonococcal arthritis seen in the Bellevue Hospital in New York, in which treatment by different comparative methods was instituted, Lowsley's [58] views on treatment are as follows: In the acute cases he advises rest in bed and massive doses of gonococcal vaccine, which allays pain in many instances; the joint should be completely immobilized for two weeks and then the splint removed for daily mobilization and physiotherapeutic measures. If the seminal vesicles are distended with pus which cannot be emptied by stripping, excision is to be advised and may be expected greatly to benefit the condition. Lowsley believes that possibly the operation might be wisely performed in the early stages of a gonococcal arthritis. After the acute joint symptoms have subsided, the seminal vesicles and prostate should be treated until they are cured; otherwise a slumbering volcano exists.

Cunningham [59] believes that the importance of chronic infection of the prostate and vesicles as a source of infection in chronic arthritis is not sufficiently recognized. The gonococci may have died out and left in their wake pyogenic cocci. Cunningham has been impressed with the poor results of nonoperative treatment, estimating the failure

57. Roello: Riforma med. **37**:654 (July 9) 1921.
58. Lowsley: New York M. J. **113**:641 (May 4) 1921.
59. Cunningham: Surg., Gynec. & Obst. **32**:501 (June) 1921.

of these methods at 90 per cent. He admits that the operation of removing most of the vesicles and draining the prostate is difficult; but he considers the results brilliant. It renders the patients sterile, but not impotent. His later experience following his reported 120 cases has confirmed his enthusiasm.

[ED. NOTE.—It is well for us to consider these views of well known genito-urinary surgeons concerning this obstinate form of arthritis. In the acute fulminating cases, arthrotomy and lavage and closure may be expected to arrest the local process and conserve joint motion. Many of the subacute joints subside under fixation alone. The satisfactory immediate local results may tend to make us careless in insisting on careful genito-urinary after-treatment, and, as Towsley says, leave the patient with a slumbering volcano which later may cause a chronic deforming arthritis hard to overcome.]

Roentgenologic Appearances of Gonorrheal Arthritis.—Costa and Garcin [60] have systematically examined the roentgenograms of 200 cases of gonorrheal arthritis. They conclude that there is no characteristic type of change to be discovered. The appearances are varied, and, while in a general way osteoporosis is always found, there are many other bizarre changes which make it impossible to typify the findings.

Intermittent Hydrarthrosis.—Bierring [61] has reviewed the literature of this peculiar affection, finding seventy-six cases and adding one of his own. Patients of all ages are susceptible to the disease; it attacks the sexes equally, and trauma is a negative factor. One or both knees were involved in all the cases, the elbow in three cases, the ankle, hip, and wrist in one each. He assumes that transitory influences, acting either through the circulation or the nervous system (psychic or reflex), mildly infective or toxic, can produce this unique syndrome. The condition, while persisting for many years, tends to improve and gradually ceases.

GOUT

Oxalic Acid Gout.—Loeper [62] has written many articles on this subject during the last ten years and his experience leads him to a firmer conviction of the pathologic action of oxalic acid retention. The joints suffer most from a deforming hypertrophic arthritis, involving mostly the small joints of the hands. The connective tissue and bones are chiefly affected in an oxalemia in contradistinction to the uric acid affection of the cartilage and periarticular tissues. In true gout the blood pressure is high; in oxalic acid gout the blood pressure

60. Costa and Garcin: J. de radiol. et d'électrol., February, 1921.

61. Bierring, W. L.: Intermittent Hydrarthrosis, J. A. M. A. **77**:785 (Sept. 3) 1921.

62. Loeper: Médecine **2**:768 (July) 1921.

is low and an anemia exists. The excess may be eliminated in time by a freshet through the kidneys. The most common disturbances in oxalemia are gastro-intestinal and urinary, owing to the injury caused by the elimination of the crystals of calcium oxalate. The bones may become porous from loss of calcium. Rhubarb, chocolate, the purins, and nucleins should be eliminated from the diet. Phosphorus for its remineralizing action and magnesium preparations as antidotes for the oxalic acid should be administered.

True Gout.—In an editorial in the *Journal of the American Medical Association,*[63] the problem of gout is discussed. Thannhauser and Czoniczer have shown that it is not faulty metabolism of the precursors of uric acid in the blood that leads to gout. The view is generally held that the human organism is virtually incapable of destroying uric acid, so that failure to destroy can play no part in the etiology. It seems a fundamental fact that the kidneys rather than the tissues, or faulty metabolism, are a prime factor. Interest remains centered, therefore, on the problem of elimination.

BOOK REVIEW

GOUT: With a Section on Ocular Disease in the Gouty by W. M. Beaumont. By LLEWELLYN JONES LLEWELLYN. Cloth. $7.50. Pp. 469, with one illustration. St. Louis: C. V. Mosby Company, 1921.

This large octavo of 469 pages is more likely to terrify than to attract the busy physician, particularly in America, where gout is a rare disease. Nevertheless, a perusal from cover to cover will prove of value to those desiring a comprehensive survey of the subject. The author, who holds the position of governor and senior physician at the Royal Mineral Water Hospital at Bath, writes in a delightful style and from a background of rich clinical experience. He has not spared himself in searching the literature, both ancient and modern. Particularly to be commended are the chapters on the metabolism of proteins, nucleins, and uric acid. One feels that the chapters on therapeutics are tinged by his own experience with spa treatment. His conclusions that gout is due to inherent metabolic defects and that the acute paroxysms are the result of bacterial invasion from foci of infection may not be accepted by all; but no one can disagree with the statement that neither the purely chemical nor the physical theory is alone sufficient to explain the phenomena of the disease at present.

RETROCALCANEAN BURSITIS

This annoying affection of the bursa between the insertion of the Achilles tendon and the tuberosity of the os calcis may be caused by too short shoes or by an infection. There is local tenderness and swelling. The application of high heels may avert surgical intervention. Nielson [64] reports a rapid cure as a result of this simple expedient.

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63. The Problem of Gout, Editorial, J. A. M. A. **76**:1578 (June 4) 1921.

64. Nielson, A. L.: Diagnostic and Therapeutic Point in Retrocalcanean Bursitis, J. A. M. A. **77**:463 (Aug. 6) 1921.

[ED. NOTE.—Transverse strapping with adhesive plaster and removal of the posterior portion of the counter of the shoe may also be expected to relieve the irritation and cause subsidence of the acute condition. Roentgenograms will frequently show a very sharp corner amounting to an abnormal prominence of the superior posterior portion of the os calcis; and surgical removal of this is sometimes necessary to avoid repeated irritation of this superficial bursa.]

RICKETS: OSTEOCHONDRITIS JUVENALIS (LEGG-CALVÉ-PERTHES): OSTEITIS FIBROSA

Rickets.—An experimental study carried on at the University of Glasgow by Paton and Watson[65] on dogs led them to the following conclusions: (1) In young dogs under laboratory conditions liberal allowance of milk fat neither prevents the onset of rickets nor cures it when developed. (2) Pups kept in the open air may escape the development of rickets on an intake of less than 1 gm. of milk fat per kilogram of body weight. (3) Scrupulous care as to cleanliness is of greatest importance in pups reared in the laboratory in order to prevent rickets. (4) The results of these experiments do not support the conclusion of the Accessory Food Factors Committee of the Medical Research Council that rickets is a deficiency disease due to lack of an antirachitic factor associated with milk fat.

Mackay,[66] working with kittens, at the Lister Institute in London, has reached the same conclusions as those of the American investigators, namely, that Mellanby's claim that the ultimate cause of rickets is a substance identical with fat-soluble vitamin A, is not substantiated. Kittens fed on a diet, generally adequate, but deficient in vitamin A, become emaciated, cease growing, have diarrhea, and show abdominal distention; but at postmortem, Tozer[67] found no evidence of rickets. Hess, McGann, and Pappenheimer have reached similar conclusions. Recent perfection of technic has made possible the study of the inorganic elements of the blood, and Howland and his associates have shown that deficiency in the calcium content of the blood is not responsible for rickets. On the other hand, the inorganic phosphorus of the serum is said to be reduced always in active rickets. Normally, the ratio of the concentration of calcium to that of phosphorus in the serum of nonrachitic children is almost identical to the ratio in the tertiary phosphate whch makes up about 90 per cent. of the salts of normal bone. The deficiency in phosphorus in the serum found so constantly in rickets would seem to cause a difficulty in the precipitation of this tertiary phosphate. In healing, apparently from some unknown

65. Paton and Watson: Brit. M. J. **1**:594 (April 23) 1921.
66. Mackay: J. Biol. Chem. **15**:19, 1921.
67. Tozer: J. Biol. Chem. **15**:28, 1921.

cause in the spontaneous cases or as the result of the administration of cod liver oil, the normal calcium phosphorus balance becomes restored. The finding of a low content of inorganic phosphorus in the serum of a young child, for example, 3 mg., or less, per hundred c.c., would seem to indicate active rickets.

McCollum, Simmons, Shipley, and Park [68] have shown experimentally that in the rat, faulty rations containing 2 per cent. of added calcium carbonate give rise to pathologic conditions in the skeleton essentially identical with those found in human rickets. The cartilage undergoes degenerative and metaplastic changes and fails to take up calcium phosphate with any regularity. These rachitic changes occur when there is disturbance in the optimal ratio between calcium and phosphorus in the absence of an organic substance, supplied, for example, by sufficient quantities of cod liver oil. So far as calcium and phosphorus are concerned, the experiments seem to show that the physiologic relation between the two is of infinitely greater importance in insuring normal calcification than the absolute amount of the salts themselves.

Sherman and Pappenheimer [69] reach almost the same conclusions as a result of dietary experiments in white rats. They say that while in their experiments the addition of potassium phosphate to the diet increased the assimilation and normal deposition of calcium, it may be the quantitative relationship between the inorganic ions rather than the actual deficiency of any one of them which was the determining factor in the cause or prevention of rickets.

Hess and Unger [70] report that by the ultraviolet ray they are able to bring about a cure of rickets, and in the paper here reviewed they state that marked improvement, as shown by muscle tone, roentgenologic examination, and general condition, has resulted from direct exposure to the sun's rays. Even relatively short exposures, for example, those of 25 degrees, in two weeks showed definite results.

[ED. NOTE.—The problem of rickets seems suddenly to be nearer solution than ever before. The restoration of the normal calcium phosphorus balance seems to be the essential chemical factor in bringing about a recovery, and various internal medications seem capable of restoring this balance. The striking curative effect which certain forms of radiation produce is quite startling. Park's last paper, read before the National Association for Child Hygiene, confirms the curative effect

68. McCollum, Simmons, Shipley and Park: J. Biol. Chem. **47**:507 (Aug.) 1921.

69. Sherman and Pappenheimer: J. Exper. Med. **34**:189 (Aug.) 1921.

70. Hess, A. F., and Unger, L. J.: The Cure of Infantile Rickets by Sunlight, J. A. M. A. **77**:39 (July 3) 1921.

of sunlight. Without any internal medication whatever, exposure to the sun's rays may be expected to result in a return to the normal deposition of calcium.]

Thorax in Rickets.—Park and Howland [71] have pointed out that the skeletal changes in the course of severe and prolonged rickets may threaten life and even cause death. The chief danger is from loss of rigidity of the thorax. The respiration becomes enfeebled by the depression, at first dynamic and later static, of the sides of the thorax, whose size becomes diminished. Atelectasis of the lungs may ensue; the pulmonary circulation becomes impeded, and hypertrophy of the right side of the heart follows. If such a respiratory mechanism, barely able to perform its task, is subject to an intercurrent infection, it fails. It is difficult to control these changes by any orthopedic appliance, and reliance must be placed on prophylactic measures (cod liver oil and sunlight) and the avoidance of abdominal distention. The seriousness of these thoracic deformities has also been emphasized by Brusa,[72] who reports five cases of bronchopneumonia in children with rachitic deformities of the chest. Two of these patients died.

Osteochondritis Juvenalis, Coxa Plana (Legg-Calvé-Perthes Disease).—Calvé [73] proposes the term coxa plana for this condition. He considers that the inflammatory process, whatever its nature, is buried so deep in the cartilaginous epiphysis that it does not reach the joint surface, but temporarily destroys the ossification center, which later regenerates. His theory is so closely in accord with the findings in a very carefully worked up case of Phemister [74] as to be extremely interesting. Phemister encountered a "typical" case in a boy of 10. Recumbency with traction had entirely relieved the slight pain; but the limp had persisted and increased. There were no constitutional symptoms. The roentgenologic findings were entirely characteristic of the condition. An exploratory operation demonstrated turbid, straw colored joint fluid and a mild synovitis. A window, 1 cm. square, was removed from the smooth, shining, flattened head, extending into the center of ossification, and including a small portion of the epiphyseal line. It was then seen that this center of ossification was almost entirely broken down in its lateral portion and a cavity existed, partly filled with granulation tissue and partly with débris in which were several sequestrums. The cultures and guinea-pig inoculations were all negative. The histologic picture was that of an old, probably pyogenic, infection, which had destroyed most of the bony center in the

71. Park and Howland: Bull. Johns Hopkins Hosp. **32**:101 (April) 1921
72. Brusa: Rev. d. chir. e ped. **29**:210 (April) 1921.
73. Calvé: Presse méd. **29**:383 (May 14) 1921.
74. Phemister, D. B.: Operation for Epiphysitis of Head of Femur, Arch. Surg. **2**:221 (March) 1921.

head of the femur. The hip was immobilized in a plaster spica for two months and a roentgenogram at the end of five and three-fourth months showed the defect entirely filled up with new bone and the size of the bony center slightly greater than before operation. Phemister considers that the operative and pathologic findings point strongly to an infectious nature of the disease. It is a common experience to obtain negative cultures in cases of mild localized osteitis of long duration. The center of ossification is surrounded by cartilage, and as Calvé points out may not be easily penetrated and keeps the infection localized. After some months, the infection may penetrate the narrower epiphyseal line and produces the changes in the neck which have been often noted. Cartilage is not penetrated by nerve fibers and the center of ossification is without nerve supply, which explains the common absence of pain. Legg and Kidner have both reported cases in which the epiphyseal line had been perforated and a broken down process was curetted from the adjacent neck, the culture showing staphylococcus.

Osteitis Fibrosa.—Bryan [75] reports an instructive case of osteitis fibrosa in a child of 10. A pathologic fracture of the humerus had occurred and the entire diseased section of the humerus, 4 inches (10.2 cm.) long, was excised. A boiled beef bone graft, 5 inches (12.7 cm.) long, seven-eighths inch (22.2 mm.) wide, and one-third inch (8.5 mm.) thick, drilled with holes in the ends and sides, was inserted and healed perfectly with ingrowth of new bone. The roentgenogram showed a rarefied and expanded area in the upper third of the humerus. The pathologic report was: "The continuity of the bone shaft is lost in an irregular mass of new tissue, which is pink in color, of great firmness, and not very vascular. This tissue occludes the medullary cavity and no cysts are present. Histologically, the mass consists chiefly of firm fibrous tissue in which there are very few blood vessels. In some parts a more cellular growth is found consisting chiefly of spindle shaped cells. The transition from spindle shaped cells to firm fibrous tissue can be observed in the section. With the spindle cells are many multinuclear giant cells, but their character does not suggest malignancy."

FOOT STRAIN: POSTURE: SCOLIOSIS

Mechanism of Human Foot in Walking.—Gibson [76] suggests that the term arches of the foot is really not descriptive, for an arch is a structure which remains in a fixed position. The kinetic mechanism of the foot is really a series of springs: a short hard spring on the lateral aspect of the foot, and a long flexible spring on the mesial aspect of

75. Bryan: Lancet **1**:129 (May 28) 1921.
76. Gibson: J. Orthop. Surg. 3:188 (May) 1921.

the foot. In the art of walking the weight first borne on the heel is shifted to the outer side and transmitted through the heads of the metatarsals (the anterior transverse spring) to the long flexible mesial spring. As in other machines, the long flexible spring is most likely to give way when a deforming stress is applied, either too great in amount or for too long a time for the spring to recover completely. By exercise the muscles which support these springs must be made strong enough to do their work.

Three Frequent Causes of Weak Feet.—Rugh [77] enumerates three anatomic-mechanical defects which may induce foot strain: (1) shortening of the Achilles tendon. In trying to compensate for the inability to flex the foot dorsally to 90 degrees, these patients toe out and this tends to produce foot strain. (2) Hypertrophy of the mesial border of the scaphoid, which as a congenital or developmental change, hooks round the mesial border of the astragalus and blocks adduction of the foot; and (3) the presence of the supernumerary tibiale externum just back of the scaphoid, making adduction less free.

Posture and Ptosis.—Parlavecchio [78] describes in detail three causes for the symptoms arising from ptosis of the abdominal organs: (1) the effects due to the mechanical displacements; (2) the effects due to the concomitant endocrine disturbance, and (3) the effects due to the changes in the sympathetic system.

Dickson,[79] writing on the effect of posture on the health of the child, reports a study of forty-eight cases. He concludes that the symptoms are due to muscle strain and fatigue, early visceral ptosis and the concomitant gastro-intestinal disturbances. In his series there were twenty-four cases of hip or knee pain all relieved or cured by postural treatment; twenty-eight cases of fatigue and overtire, all completely relieved; ten cases of failure to gain weight, all of which patients were improved; twenty-one cases of nervous irritability, in twelve of which the symptoms disappeared, and were improved in six. Twelve patients complained of restlessness at night, and nine of these were improved; fifteen complained of constipation, eight were cured, four improved, and three unaffected; two had periodic gastro-intestinal attacks, and in one these disappeared and in one they were greatly lessened.

Scoliosis.—Bradford [80] looks upon spinal curvature not as a definite disease but as a fault of growth; and his treatment is based not so much on correction of the curves as upon guidance of growth toward

77. Rugh: Ann. Surg. **73**:499 (April) 1921.

78. Parlavecchio: Riforma med. **37**:481 (May 21) 1921.

79. Dickson, F. D.: Effect of Posture on Health of Child, J. A. M. A. **77**:760 (Sept. 3) 1921.

80. Bradford: Boston M. & S. J. **184**:512 (May 19) 1921.

a normal standard of trunk shape and carriage. Easily tired backs should be rested, backs with weak muscles should be strengthened, and stiff portions of the spine should be made flexible. His conclusions from his wide experience are that flexible curves without structural changes in healthy patients can be restored to normal, even when some abnormal stiffness is present. Fixed rotary curves require energetic measures if improvement is to be expected, even in young children. He does not consider it a difficult task, as a rule, to prevent the increase of the curvature in healthy adolescents if careful treatment can be carried out for a long period.

SURGERY OF THE PERIPHERAL NERVES

Worster-Drought [81] believes that injuries to the posterior tibial nerve are frequently overlooked because they cause no striking paralysis. The movements at the ankle are normal; and if the lesion lies below the origin of the nerves to the flexor longus hallucis and flexor longus digitorum, the power of flexing the toes remains. Loss of sensation in the plantar region and loss of power in the intrinsic muscles of the foot are signs of posterior tibial nerve lesion. These diagnostic signs should be borne in mind in all wounds of the calf followed by pain and weakness in the foot. Babcock and Bower [82] report end-results of 608 cases of peripheral nerve injury. They performed three types of operation: (1) simple neurolysis, that is, freeing the nerve and splitting the sheath to determine the condition of the contained bundles, the tests for conductivity being made with a small faradic coil; (2) hersage, consisting of freely but carefully splitting the trunk in a number of longitudinal planes if the interior of the nerve was found to be fibrous or cicatricial. If no nerve fibers were seen, these incisions were continued until the undamaged portions of the nerve were connected by multiple fine fibrous fibrils. There were 169 such cases and only twenty-five, or 14 per cent., showed no improvement. One patient was made worse. (3) Suture, the ends of the divided nerves being trimmed with a sharp razor blade until well formed nerve bundles were shown, and then very accurate approximation was obtained by finest black silk sutures. Of 182 sutures, only eight showed failure of regeneration and in all of these some mechanical feature was found to account for the lack of regeneration. Large gaps were treated by extensive freeing of the nerves, transposition and flexion of the neighboring joints.

[Ed. Note.—We gain the impression from this article that the results reported are much more favorable than those which other well qualified surgeons have been able to attain. Drs. Babcock and Bower owe it to the profession to present a still more detailed account of

81. Worster-Drought: Brain **44**:54 (April) 1921.
82. Babcock and Bower: Pennsylvania M. J. **24**:533 (April) 1921.

individual cases, types of lesion, and final end-results in quantitative function. In relation to this very hopeful article, the review of Platt's work which follows is interesting.]

Platt[83] has analyzed the results in 510 cases in which he has operated between March, 1915, and December, 1920. Two hundred and forty-eight of these patients he has examined six months or more after the operation. He realizes that not all of them can be considered true end-results. Of 150 end-to-end sutures, there were only five musculospiral nerves and two external popliteal nerves which regained complete and perfect recovery. The factors which militate against this he considers to be: (1) period of delay between injury and operation, there being apparently little difference in the amount of improvement up to eighteen months, after two years the improvement appearing much more slowly or not at all; (2) recrudescence of septic infection in the limb; (3) anatomic situation of the suture; (4) influence of topography; (5) influence of perineural surroundings—the nerve bed; (6) influence of complications, and (7) continuance of active interstitial neuritis in the proximal segment of the nerve. He is led to believe that in complete lesions of the median and ulnar nerves in the upper arm, restoration of function in the proximal muscles is to be expected even after long periods of delay, but distal recovery is unlikely. Exploration in these cases is generally advisable; but unless resection and suture are performed, little or nothing can be expected. This total resection and suture may be unjustifiable. In complete lesions of the median and ulnar nerves in the forearm, the restoration of sensation in the median distribution is of such great importance as to warrant any well conceived procedure to attain it. In lesions of the median nerve in which partial sensory conduction is present, even with complete motor loss, resection and suture are at the present time to be condemned. In ulnar lesions in which only the intrinsic musculature is affected, resection and suture are to be advised. In the complete sciatic lesions, in which end-to-end suture is possible, the procedure may be expected to succeed. In musculospiral lesions, exploration of the nerve should precede tendon transplantation.

Maud Forrester Brown,[84] convinced that little or nothing can be expected from nerve bridgings, enumerates the procedures by which more length can be gained for end-to-end suture: (1) By extensive freeing of the nerve from its bed; after this has been done, 1½ inches (3.8 cm.) can be gained for the median and ulnar in the upper arm and 1 inch (2.5 cm.) in the forearm. By freeing the sciatic in the thigh, 2 inches (5 cm.) can be gained. (2) By fixing the neighboring joints in certain positions; adduction of the arm at the shoulder gives an

83. Platt: Brit. M. J. **1**:596 (April 23) 1921.
84. Brown: J. Orthop. Surg. **3**:277 (June) 1921.

added inch to the median, ulnar, musculospiral, and musculocutaneous. Flexion of the elbow gains 2 inches (5 cm.) for the median and 1 inch (2.5 cm.) for the musculospiral. Extension of the elbow gains 1 inch (2.5 cm.) for the ulnar. Flexion of the wrist gains 1½ inches (3.8 cm.) for the median and ulnar in the forearm. Flexion of the knees gains about 2 inches (5 cm.) to the sciatic and popliteals. (3) By altering the course of the nerve—transposition; for the ulnar, two-thirds inch (17 mm.) may be gained by this method, and an inch (2.5 cm.) for the musculospiral. (4) By stripping up any anchoring branches; extra stretch can be gained in this manner for the musculospiral, median, ulnar, sciatic, internal popliteal, and posterior tibial. The external popliteal and posterior interosseous do not lend themselves to this expedient. (5) Sacrificing branches above the lesion and compensating for the motor disturbance later by tendon transplantation are sometimes justifiable. The median has been thus lengthened 6½ inches (16.5 cm.). (6) In ununited fractures the shortening of the bones is often helpful. (7) Two-stage operations often gain from 2 to 3 inches (5 to 7.6 cm.). Of eleven cases thus lengthened there have been signs of beginning return in nearly all and in two definite sensory and motor return though not absolutely complete.

Ney [85] prefers local anesthesia for nerve operations after a wide experience. Identification sutures he believes greatly aid in preventing torsion. He considers transposition of the ulnar and musculospiral anteriorly and transposition of the median to a position superficial to the superficial head of the pronator radii teres valuable aids in gaining length. The muscular branches must be mobilized intraneurally in order to be able to do this. If in addition flexion relaxation of joints and two-stage operations are employed, the necessity for nerve bridging practically never occurs.

OSTEOMYELITIS

Acute Osteomyelitis of Long Bones in Children.—Mitchell [86] divides acute osteomyelitis of the long bones in children into three types: (1) localized infection at the end of a long bone with a comparatively long history and no severe general infection (Brodie's abscess?). Treatment by removal of all bone denuded of periosteum will allow for drainage of the medulla, which should not be curetted. (2) A short history of trouble, twenty-four hours or less, severe general infection with strictly localized exquisite tenderness on pressure at one end of the shaft. Treatment by incision will often reveal no pus, but the periosteum will be found beginning to separate over a small area. The bone should be opened freely and usually a little pus will be detected.

85. Ney: Ann. Surg. **74**:37 (July) 1921.
86. Mitchell: Brit. M. J. **1**:807 (June 4) 1921.

Drainage of these early cases will be followed by a speedy convalescence. (3) The most common type is the acute type, in which there is considerable denudation of the periosteum, in the acute cases over the whole shaft. Mitchell believes that the removal of the whole thickness of the shaft over the whole area of denudation is indicated. A Gigli saw is used and treatment with surgical solution of chlorinated soda (Carrel-Dakin solution) instituted for a few days and then a secondary suture made. A Thomas splint is applied and active early movement of the muscles allowed.

Acute Hematogenous Osteomyelitis.—In interesting contrast to this radical treatment advised by Mitchell are the conclusions reached by Bancroft[87] after careful experimental work and a large clinical experience. He has produced a chemical osteomyelitis in animals by inserting capillary tubes filled with croton oil into the medulla. An involucrum and extensive sequestrums have been formed and the other changes characteristic of clinical osteomyelitis. These sequestrums, no matter how extensive, have always been absorbed and replaced by new bone. He concludes from these experiments that sequestrums in acute infectious osteomyelitis would behave in the same manner if it were possible to sterilize them. He reports also eleven cases of acute hematogenous osteomyelitis treated at the New York Hospital. Sixty per cent. had a history of trauma, and some previous experiments of Bancroft confirmed Lexer's findings that it is often possible to produce osteomyelitis in animals by traumatizing a bone and then introducing staphylococci intravenously. These eleven clinical cases were typical children's cases and the bones were usually involved near the metaphysis. One child died within twenty-four hours after admission. All the others are well save one, who had a small persisting sinus when last seen, two years ago. Several had metastatic joint infections, for which he advises only aspiration and irrigation, unless drainage proves absolutely necessary. In the acute stage he advises drainage with removal of a shell of cortex, followed by Carrel-Dakin treatment. In the septicemic cases he found the intravenous injection of commercial peptone most useful. In the subacute stage in which the patient is progressing favorably he is convinced that bone which appears dead may frequently be saved, and he advises against too radical an operation. The roentgenograms of his cases show great diminution in the size of the sequestrums under conservative treatment. He believes that Carrel-Dakin treatment disinfects dead bone, which then behaves like any bone graft.

87. Bancroft: Ann. Surg. **73**:681 (June) 1921.

Osteomyelitis Following War Injuries.—Stephens,[88] reporting on work at a Public Health Service hospital, found 35 per cent. of the cases to consist of an osteomyelitis following war wounds. This osteomyelitis is extremely chronic and it is almost impossible to determine when a case is cured. This emphasizes the importance of efficient early treatment. In these chronic cases operative treatment is almost always indicated. All remaining foreign bodies and sequestrums should be removed and disinfection should be attempted. When this has been accomplished, the cavity should be obliterated by filling the space with overlying soft parts or a muscle flap. Conservative rather than radical treatment should be employed.

Wood[89] also has become convinced that the pedicle muscle flap is the most efficient plug. It is living, with its own blood and often nerve supply. It acts as a hemostat and is able to resist low degrees of infection.

Hedri[90] reports surprisingly satisfactory results in closing osteomyelitic bone cavities by the method of Payr of Leipzig. A large flap of skin and subcutaneous tissue is planned with a proximal pedicle. A smaller muscle flap is fashioned with a distal or lateral pedicle. Lifting this flap, the bone cavity is exposed and thoroughly cleaned out and wiped with Lugol's solution. The muscle flap is immediately turned in and the skin flap sutured in place over it. In eight cases permanent healing was primary and in six it was secondary, but with no sinus. Two cases healed with a sinus which closed in three months. Six patients are still in the ward, but all cases bid fair to heal without a sinus within six weeks after the operation. The roentgenograms show an obliteration of the cavity after six months.

Subacute Osteomyelitis of the Spine.—Kidner[91] presents three cases of spinal lesion which he believes represent low grade pyogenic infections similar to the Legg-Calvé disease of the hip. The localization of the disease in a small area of bone, the slight tendency to collapse, the new bone formation, and the tendency to recovery make Kidner believe that we are dealing with a staphylococcus of low vitality. Early operative fixation of the diseased area apparently brings about a speedy cure.

Pathogenesis of Osteomyelitis.—Hobo[92] demonstrates in a handsomely illustrated article that bacteria tend to accumulate at the points of sluggish flow of the blood stream. This occurs most frequently in the venous capillaries of the bone marrow, liver, and spleen. The

88. Stephens: J. Orthop. Surg. **3**:138 (April) 1921.
89. Wood: Brit. J. Surg. **8**:460 (April) 1921.
90. Hedri: Zentralbl. f. Chir. **48**:698 (May 21) 1921.
91. Kidner: J. Orthop. Surg. **3**:459 (Sept.) 1921.
92. Hobo: Acta scholae med. univ. imp., Kioto **4**:1 (March) 1921.

capillaries of the marrow are extremely tortuous; and conditions are most favorable for their accumulation and extremely unfavorable for phagocytosis.

BONE, JOINT, AND TENDON SURGERY

Transplantation of Bone.—An article by Durand [93] deserves comment. It is a complete review of the history of the so-called bone graft, the earliest reference to the employment of this method being in 1670. He discusses the various forms of graft which have been employed and are being employed and states his belief as to their comparative value and applicability.

Delagénière [94] advocates the osteoperiosteal transplants and describes his technic. He looks upon them not as grafts but as implants of those elements indispensable for the new formation of bone. He takes issue with Albee, declaring that by their employment it is possible to reconstruct any portion of the skeleton and cure any pseudarthrosis much more certainly than with the Albee method. He employs transplants of about 1 mm. in thickness, consisting of periosteum lined with a thin layer of bone. Operations on the jaw, nose, skull, or shoulder are illustrated.

Haas [95] reports another careful piece of experimental work, this time to determine the influence of function in relation to transplantation of bone. From one paw of an animal, a metatarsal, metatarsophalangeal articulation and a proximal phalanx were removed and transplanted into the muscles of the back. In the other paw the same elements were completely removed and then reimplanted in their original bed. These reimplanted bones lived and developed normal density under functional use. The same elements implanted into the back muscles degenerated and completely disappeared in three years. He concludes, therefore, that function exerts a definite influence upon the viability of transplanted bone. Bony union between the transplant and the host is essential; and functional use should not be instituted until this union is well established.

Henderson [96] reviews 413 cases of bone transplantation performed at the Mayo Clinic during the last eight years. Of 166 cases of spinal caries in which operation was performed by the Albee technic with slight modifications, he has been able to trace 132 patients on whom the operation had been performed at least eighteen months previously. Only nine of these were children. When patients were free from pain

93. Durand: Lyon méd. **130**:473 (June 10) 1921.

94. Delagénière: J. de chir., Paris **17**:305 (April) 1921.

95. Haas, S. L.: Function in Relation to Transplantation of Bone, Arch. Surg. 3:425 (Sept.) 1921.

95. Henderson, M. S.: Autogenous Bone Transplantation, J. A. M. A. **77**: 165 (July 16) 1921.

and able to resume wage earning occupations the disease has been classified as arrested or cured. Exactly 50 per cent. of these 132 cases were thus classified. Of the patients 21.99 per cent. were improved; 16.66 per cent. were unimproved; 9.09 per cent. died later of disseminated tuberculosis, and there was a 2.26 per cent. operative mortality. Only 2.4 per cent. had postoperative infection. Occasional complications were: loss of graft, two cases; fracture of the graft, four cases; loosening of one end of the graft; ulceration over the prominence of a large kyphos.

Two hundred and forty-seven patients were operated on for delayed union, nonunion, and other conditions, and more than half of these had been previously operated on elsewhere. Fifty-nine of them had been infected and in many there was much scar tissue and the skin was often adherent to bone. Two hundred and twenty-three of the patients have been traced, and on these 176 operations had been performed. Of these operations, 72.16 per cent. were successful, 85 per cent. of the tibia cases, 50 per cent. of the femur cases, and 60 per cent. of the humerus cases. There were four deaths. In 247 operations, there was infection following 15.7 per cent. of the operations; in 9.9 per cent. of the clean cases, and in 41.3 per cent. of the previously infected cases. The method which Henderson now employs is the inlay graft, fastened in place with bone screws. He has abandoned the use of the intramedullary transplant because of the poor results.

Loose Bodies in Joints.—Fisher[97] in a Hunterian Lecture before the Royal College of Surgeons, England, has made a very complete study of loose bodies composed of cartilage or of cartilage and bone occurring in joints, with special reference to their pathology and etiology. He reminds us that Sir James Paget's theory of "quiet necrosis or osteochondritis dessicans" has been interpreted by American authors as a dissecting process and called "dissecans." Under the pathology and symptomatology, he makes three groups of bodies: (1) Those occurring in connection with some more or less general pathologic process, for example, osteo-arthritis, tabes, tuberculosis, or infection. (2) Loose bodies formed from a detachment of a portion of the articular cartilage in otherwise normal joints. Proliferative changes in these loose bodies take place when they are incompletely detached or form reattachments. (3) Synovial chondromas. Etiologically, he believes the second group represents true traumatic detachments. Pathologically, he believes that clinically and experimentally the cells retain their vitality and after a time actually proliferate. He is convinced of this in spite of Redfern's dictum that cartilage cells are destitute of the power of repair. The nutrition of articular cartilage

97. Fisher: Brit. J. Surg. **8**:493 (April) 1921.

may come from the synovial fluid, from plasma exuded from capillaries in the cancellous spaces, abutting on the calcified layer of the articular cartilage, or from plasma from the plexus of vessels beneath the synovial membrane at the margin of the articular cartilage. In loose bodies quite free in the joint, there is no evidence to show any proliferation of the osteoblasts. On the other hand, loose bodies of traumatic origin which have acquired an early attachment to the synovial membrane show active proliferation of osteoblasts, with formation of new bone. He discusses the classical symptoms of locking, which may be present for a period, to disappear if the body becomes attached and sessile, and reappear if it again becomes free. He considers the treatment operative, always preceded by roentgenologic examination. He considers the method of transfixing with a needle and removal through a button hole incision as unscientific and likely to be incomplete.

ARTHROPLASTY

Putti [98] considers, in enlightening detail, the indications and contraindications for arthroplasty. His views are based on an experience of ten years, during which time he has performed 113 mobilizations. The absolute indications for such attempts he considers to be ankylosis of the temporomaxillary joint, bilateral ankylosis of the hip joints, ankylosis of the elbow in extension, and ankylosis of several of the important joints in one limb. In determining the indications in cases other than these, he believes that the surgeon must carefully consider: (1) the general health of the patient; (2) his age; (3) his mental condition and social state. Between 20 and 50 years is the most favorable age. Men do better than women. The posttraumatic arthritides present the most favorable group. The results are better in the cases of bony ankylosis than in the painful fibrous ankylosis. After an infectious arthritis any thought of an operation for mobilization must be deferred until at least a year has elapsed after the subsidence of joint sensitiveness. At present Putti considers that ankylosis is the best result in tuberculous arthritis. In connection with arthroplasty of the knee, Putti believes that it should be advised only when a precise indication is present and should be undertaken only by a surgeon who has acquired great skill in the reconstruction of joints. Under these conditions he believes that it should be accepted with greater faith and executed more frequently. The essential operative methods are these: (1) A complete exposure of the joint. (2) In functional reshaping of the articular ends, resection of enough bone to provide a space of at least 1 inch (2.5 cm.) between the ends is advisable. (3) Free aponeurotic (fascial) flaps should completely cover both ends. (4) Drainage should not be employed. After the operation the joint should be immobilized in

98. Putti: J. Orthop. Surg. **3**:421 (Sept.) 1921.

plaster with distal traction. Hot air treatment is begun as soon as the wounds are closed. Painless mobilization is begun on the tenth day, but traction is maintained for a month. In Putti's series the highest percentage of successful results has been obtained in the elbow, the next highest in the knee, the third in the jaw, and the fourth in the hip. There were two operative fatalities.

Campbell [99] reports the results of twenty arthroplastic operations on the knee, in which he has employed pedunculated flaps, free fascia, and absorbable membranes. In four cases the membrane was extruded. In three the failure was, in Campbell's opinion, due to the dense low grade osteomyelitic bone through which the operation was performed. Of the remaining thirteen patients, nine obtained some voluntary motion, in four of these not sufficient to be of practical use, but in five enough to provide satisfactory function, making the successes in his series 25 per cent.

Typhoid Bone and Joint Disease.—Wilson [100] reports a case of typhoid osteitis from which cultures both from swab and from removed bone showed a growth of pure *Bacillus typhosus*. The Carrel technic was instituted for four days and then secondary suture was successfully accomplished.

Bureau and Marchand [101] illustrate the fact that typhoid bone lesions may become appreciable only long after the acute disease is over, by the case of a woman in whom spinal suppuration did not develop until seventeen months after the fever. This continued at intervals for two years and was finally arrested, they believe, by autogenous typhoid vaccine treatment.

Sicard and Robineau [102] also report seven cases of typhoid bone lesion in which recovery was, in their opinion, greatly accelerated by vaccine treatment. They believe that the combination of surgical treatment with autogenous vaccine therapy is usually promptly effective. They say that Rathery has obtained great benefit, especially in typhoidal spondylitis, from injection of antityphoid serum directly into the focus of disease.

Rupture of Biceps Cubiti Tendon at Insertion.—Nutt [103] describes an unusual case of rupture of the biceps tendon at its insertion into the radius. This occurred during gymnastic exercises and was accompanied by so little pain that the patient continued his exercise. Noting a

99. Campbell: J. Orthop. Surg. **3**:430 (Sept.) 1921.

100. Wilson: Boston M. & S. J. **185**:201 (Aug. 18) 1921.

101. Bureau and Marchand: Bull. méd., Paris **35**:511 (June 18) 1921.

102. Sicard and Robineau: Bull. et mém. Soc. méd. d. hôp. de Paris **45**: 465 (April 8) 1921.

103. Nutt, J. J.: Rupture of the Tendon of Insertion of the Biceps Flexor Cubiti, J. A. M. A. **76**:1825 (June 25) 1921.

difference in the contour of his arms he sought advice. The diagnosis was made and the patient was operated on the next day, the tendon being sutured. Immobilization in plaster for six weeks and the application of a right angle splint for two weeks longer was followed by gradual return of function. Three months after the operation the tendon had acquired its normal size and strength.

Snapping Finger.—In a case of snapping (trigger) finger of the right hand, Hoogveld [104] palpated an enlarged, tender portion of the flexor tendon. The tendon sheath was incised and fat tissue sutured over it without closing the sheath. All symptoms promptly ceased.

Prevention of Adhesions in Tendon Transplantation.—Lange,[105] after many experiments on animals, has employed, in more than 100 cases, thin crêpe paper to prevent adhesions in tendon transplantations. He reports great satisfaction with the method and almost complete success even when the transplanted tendon played over bone or fascia. Two layers of paper have been usually employed. The length of time of absorption depends on the thickness of the interposed paper.

Arthrodesis of the Sacro-Iliac Joint.—The operative plan described by Gaenslen [106] has been used in four cases, brief reports of which are given. A curved incision is made parallel to, and about one-half inch (12.7 mm.) above, the crest of the ilium through the skin and subcutaneous tissue extending from just behind the middle of the crest to the posterior inferior spine of the ilium. The flap is then dissected free from the outer margin of the crest. With a broad flat chisel the posterior portion of the ilium is split into an inner and outer leaf. The outer flap is broken at its base and deflected outward as far as possible, the periosteum being stripped off from the adjacent portion of the ilium just below and anterior, in order to increase the working space. With a chisel, the inner leaf of the split portion of the ilium is cut from a point just above the posterior inferior spine to the extent of 2 inches (5 cm.), extending anteriorly. A vertical cut, about 1½ inches (3.8 cm.) in length is made from the anterior end of this incision, extending upward toward the crest of the ilium to a point joining the middle and posterior third of the crest. The two points are now joined with a third chisel cut, a triangular piece of bone being removed. The destruction of the joint thus exposed is begun at the lowermost border of the sacro-iliac joint, where it is plainly in view, and is carried forward from this point, working forward and slightly outward, in general, in the direction of the anterior superior spine of the same side. After eradication of the joint, the deep trough is

104. Hoogveld: Nederlandsch Tijdschr. v. Geneesk. **1**:2663 (May 14) 1921.
105. Lange: Ztschr. f. orthop. Chir. **41**:6, 1921.
106. Gaenslen: Wisconsin M. J. **20**:20 (June) 1921.

filled with healthy cancellous bone chips removed during the course of the operation. The deflected outer leaf of the ilium is then brought into position and sutured along the crest to the inner leaf of the ilium, which has been allowed to remain standing. In several cases the inner leaf was broken off toward the medial side; but in perfecting the technic of the operation on the cadaver, it was found that the inner leaf could be left standing without adding to the difficulties of the operation.

Smith-Petersen [107] describes a new method of approach to the sacro-iliac joint for purposes of arthrodesis in tuberculosis and chronic relaxation and for drainage in osteomyelitis. A curved incision is made along the iliac crest, from the posterior superior spine forward to about two thirds of the distance to the anterior superior spine, and carried down to the bone. Subperiosteal reflexion of the flap is started. The incision is next continued from the posterior superior spine downward in the direction of the fibers of the gluteus maximus for 3 or 4 inches (7.6 or 10.2 cm.). The fibers of the gluteus maximus are separated by blunt dissection down to the bone; some of the branches of the superior gluteal nerve and artery are encountered and must be divided. The whole flap thus outlined is reflected subperiosteally, exposing the posterior portion of the lateral surface of the ilium. If the sacro-iliac joint is projected on the lateral surface of the ilium, it will be found that the inferior border corresponds with the sacro-sciatic notch and the anterior border with the median gluteal line. A rectangular window is then cut through the ilium within the projected area of the joint. In the tuberculous cases it is made about in the center of the joint surface and in the osteomyelitic cases parallel with, and close to, the sacrosciatic notch. Roughly, its size is usually 4 by 2 cm. The thickness of the ilium just above the sacrosciatic notch is considerable, sometimes 2 cm. +; but if care is taken, the plug of bone comprising the window can be removed en bloc and the joint surface is exposed. In cases of tuberculosis, the surface of the joint is curetted and all available tuberculous tissue removed; the window is continued into the sacrum, and the plug of bone cut in these cases on a slight bevel driven into it and set like a nail beneath the surface of the ilium. He reports seven successful cases of tuberculosis of the joint in the last three years, apparently firmly arthrodesed with the disease arrested, and six cases of relaxation of the joint, three successful end-results and three recent but apparently successful cases.

[ED. NOTE.—These new approaches of Gaenslen and Smith-Petersen to the sacro-iliac joint seem to us to represent real advances in bone and joint surgery. Heretofore, the only approach of which we

107. Smith-Petersen: J. Orthop. Surg. 3:400 (Aug.) 1921.

have knowledge and which was not very mutilating was Painter's,[108] which turned back a flap consisting of the whole posterior portion of ilium. This is a difficult and serious operation. Of the two methods herein proposed we can speak with first hand knowledge of only the Smith-Petersen approach; but it seems to us the simpler of the two and sufficiently complete to accomplish its purposes. In Smith-Petersen's hands the operation is a fairly rapid one, with little loss of blood and practically no postoperative shock. There has been no mortality and in cases of tuberculosis the late roentgenograms have shown what appears to be a complete bony ankylosis and an arrest of the disease. The functional results have been as completely satisfactory as the anatomic.]

Arthrodesis of the Hip for Nontuberculous Affections.—Spiers [109] has reviewed the end-results (four years or more) in twenty-five cases of nontuberculous affections of the hip joint from the Orthopedic Clinic of the Massachusetts General Hospital, in which arthrodesis of the hip joint has been attempted. In the painful hips resulting from old injuries, with only a few degrees of motion persisting, the results were satisfactory. In the cases of hypertrophic or degenerative arthritis, the improvement was not so great, and complete ankylosis was much harder to obtain. The convalescence in a long spica should be continued for a year, as the tendency to a recurrence of the adduction deformity is great. Of the twenty-five cases, union was firm in seventeen, questionable or weak in three, and incomplete in five. Fourteen were completely relieved of symptoms; seven were improved, and four derived no benefit from the operation.

Operative Lengthening of the Femur.—Putti [110] advocates lengthening many femurs shortened more than 2 inches (5 cm.). He emphasizes the necessity of continuous traction after the operation. This he accomplishes by firmly fixing large metal pins in the femur before dividing the bone, one pin in the trochanter and one in the condyles. A telescoping tube containing a strong elongating spring and controlled by a screw now connects the pins outside the skin. In performing the Z-shaped osteotomy, a motor saw is employed. He reports ten cases in which he has gained from 3 to 4 inches (7.6 to 10 cm.).

[ED. NOTE.—We have attempted, and observed the attempts of other surgeons, to lengthen femurs in young adults and older subjects, employing continuous skeletal traction to the distal fragment after Z-shaped osteotomies. Slight degrees of lengthening, from 1 to 2 inches (2.5 to 5 cm.) have been obtained. There has been a tendency to

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108. Painter: Boston M. & S. J. **159**:207 (Aug. 13) 1908.

109. Spiers: J. Orthop. Surg. **2**:515 (Sept.) 1920.

110. Putti, V.: Operative Lengthening of Femur, J. A. M. A. **77**:934 (Sept. 17) 1921.

a bowing of the fragments in spite of very heavy traction. The operation has not been without shock and the convalescence has been stormy. There are many cases which would be benefited by such a lengthening, and if Putti's apparatus proves successful in other hands it will have a considerable range of usefulness.]

Arthrotomy of the Knee.—Putti [111] describes the details of the method of approach to the knee joint which he now employs in arthroplastic operations and for purposes of resection: First, a U-shaped incision with base downward, extending from the inner part of the articular space upward around the patella to the outer part of the articular space. From the convex part of the incision a second one is made upward for 5 or 6 cm. following the lateral margin of the quadriceps ligament. This incision includes the skin, the subcutaneous tissue, and the superficial fascia. Second, isolation of the extensor apparatus. The tendinous insertions of the two vasti are separated from the quadriceps tendon and from the patella. These two incisions are carried in depth to the articular space. Third, plastic tenotomy of the quadriceps tendon. For this he makes use of what is practically two Z-shaped tenotomies side by side, each of half the tendon which has been bisected longitudinally. Fourth, freeing and reflecting downward of the patellar flap, giving a complete view of the articular cavity. Fifth, hemostasis. Sixth, reconstruction. The two flaps of the tenoplasty of the quadriceps tendon are sutured at whatever tension is desired, his method of section making it possible to elongate the tendon as much as is desired, and then the two lateral flaps of the vasti and the capsule at the sides of the patella are sutured to the reconstructed quadriceps tendon and to the patella.

Putti [112] also describes his operative method of overcoming flexor contraction of the knee. In certain cases of flexion contracture of the knee, it is impossible to straighten the knee even after lengthening the tendons, on account of the contracture of the posterior part of the capsule. In such cases Putti divides the capsule in the following manner. It first should be understood that the popliteal part of the capsule is made up of two firm bands or infundibuli, one medial and one lateral, and an intermediate fibrous septum. For approaching the capsule Putti uses a median vertical incision through the skin and superficial fascia and exposes the layer of fat which contains the internal popliteal nerve and laterally, partly hidden by the biceps, the external popliteal nerve. Plastic lengthenings of the flexor tendons are then done after which retractors are used to expose the underlying capsule. The capsule over the external condyle is first exposed and divided by

111. Putti: Chir. d. org. di movimento **5**:1 (Feb.) 1921.
112. Putti: Chir. d. org. di movimento **5**:11 (Feb.) 1921.

a transverse incision reaching to the bone. The capsule over the internal condyle is then exposed and divided in the same manner and at the same level. Finally, the intermediate septum is divided. The knee is then extended as far as the tension in the vessels and nerves allows and the wound is closed. Entire correction can be obtained in subsequent stages.

Internal Derangements of the Knee Joint.—Billington,[113] in a paper on internal derangements of the knee joint, offers the following anatomic explanation of the commonly found longitudinal splits in the internal semilunar. These splits begin at the anterior portion when the cartilage normally divides into two bands, one of which attaches to the coronary ligament and the anterior margin of the tibia just internal to the patellar ligament. The other, or posterior, division passes across as the transverse ligament and is continuous as the anterior portion of the external cartilage. When the internal condyle rotates backward, tension is made on the anterior divided portion of the internal semilunar, which is attached as above at widely divergent points, and the split may be started. The fibers of the cartilage run in a longitudinal direction and the split may be extended toward the posterior portion of the meniscus if the splitting force is continued.

Ollerenshaw [114] adds reports of three personally observed cases to the twelve already to be found in the literature of cysts of the external semilunar cartilage. There are no cysts of the internal cartilage reported. A slight injury is followed by the development of a swelling over the external cartilage, then gradually pain and lameness increase. The swelling usually occurs at the junction of the anterior and middle of the cartilage. It is fluctuant but rather tense. Ollerenshaw believes the cysts to be developmental in origin, and due to small endothelial inclusions of the cartilage during the formation of the joint. Trauma may act as the exciting agent to further the development and growth of the cyst. They have a tendency to recur after simple excision.

[Ed. Note.—One of the Editors has removed one such cyst of the external semilunar, associated with a slipping of the cartilage. We have also seen a second, apparently typical, case, also associated with symptoms of catching.]

Cotton,[115] in an article on various knee joint lesions in ex-soldiers on which he has operated, makes the statement that for lateral and anteroposterior instability he has employed, in six cases, firm bands of fascia lata implanted in the condyles of the femur and tibia, mesially and laterally, running obliquely forward and backward, or straight, as the demands of the instability require. He believes that in rupture of the crucial ligaments very useful and stable knees may thus be secured.

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113. Billington: Southern M. J. **14**:631 (Aug.) 1921.
114. Ollerenshaw: Brit. J. Surg. **8**:409 (April) 1921.
115. Cotton: Mil. Surgeon **49**:20 (July) 1921.

Nuzzi [116] has employed with satisfaction an approach to the tibio-astragaloid and subastragaloid joint through the Achilles tendon. His skin incision is curved, with the convexity proximal from the outer to the inner malleolus, and an extension upward vertically from the center of the convexity. The Achilles tendon thus exposed is divided by a Z-shaped cut; and by deeper dissection the posterior portion of the astragalus is exposed, and access to the superior and inferior articulations of the astragalus obtained for purposes of astragalectomy or arthrodesis.

New Approach to the Supraclavicular and Infraclavicular Regions.—Dobrovolskaya [117] advocates a new method of approach to the subclavian vessels and brachial plexus. His incision starts from the clavicle between the two insertions of the sternocleidomastoid muscle, running downward, and mesially, encircling the sternoclavicular joint, and continuing outward along the lower border of the clavicle. The clavicle is disarticulated from the sternum and retracted outward, with the skin flap. He maintains that the exposure of the brachial plexus thus obtained is most satisfactory.

[Ed. Note.—The approach seems to us more rational for the vessels than for the plexus.]

Manipulation of Stiff Joints.—It is the prevailing opinion that brisement forcé has little place as an operative procedure looking to an increase in the range of joint motion. A description of the methods which have enabled Sir Robert Jones [118] to obtain in so many cases so much benefit from manipulation of stiffened joints is, therefore, of great value. He has described these methods and stated the underlying principles very clearly in the article referred to above. Not forsaking the dictums of Thomas as to the value of rest and immobilization, he says we should draw a distinction between the real and the apparent, and not allow a certain timidity to prevent our taking advantage of a much ignored and little understood means of treatment.

[Ed. Note.—The Editors advise a careful perusal of this article, which is so direct and concise that it cannot be reviewed in small space.]

DISLOCATIONS

Recurrent Dislocation of the Shoulder.—Henderson [119] believes that the primary dislocation causes a tear in the anterior inferior portion of the capsule, which is the weakest and most relaxed portion and is unsupported by muscles. He conceives that the infraspinatus and supraspinatus tendons are torn by the primary injury and imperfectly

116. Nuzzi: Riforma med. **37**:701 (July 23) 1921.
117. Dobrovolskaya: Lancet **2**:129 (July 16) 1921.
118. Jones: J. Orthop. Surg. **3**:385 (Aug.) 1921.
119. Henderson: Surg., Gynec. & Obst. **33**:1 (July) 1921.

repaired by scar tissue. In certain instances the greater tuberosity is torn off. The stretching of the scar tissue takes away important muscular support and when the arm is abducted the humeral head sags downward and the action of the teres major, latissimus dorsi and pectoralis major tend to produce the dislocation by pulling the head against the weakened portion of the capsule. He reports sixteen results from the capsulorrhaphy operation which he has performed. Eight, or 50 per cent., he considers cures, and five others report great benefit from the operation.

Dislocation of the Carpal Semilunar.—C. R. McClure [120] has been able completely to reduce two recent dislocations of the carpal semilunar bone, one manually and one by the Thomas wrench. The functional results have been perfect.

Dislocation of the Sacro-Iliac Joint.—Gibson [121] reports the case of a boy of 8 years, who suffered a dislocation of the left sacro-iliac joint from a blow from a locomotive. The ilium was separated from the sacrum and a temporary paralysis of the quadriceps was present, apparently caused by a hematoma about the anterior crural nerve in the iliac fossa. In three weeks power had returned, and through a posterior incision the posterior superior spine of the ilium was divided by motor saw and the fragment implanted in the gap between the joint surfaces which were freshened. Full recovery of function followed.

Downward Dislocation of the Patella.—Rutherfurd [122] has encountered three cases of downward dislocation of the patella in three males, aged 7, 18 and 42. There was severe injury in all, the trauma being directed downward and backward, with the knee flexed. Operation brought about good results; and in two of the cases, examination of the patellar ligament and the quadriceps tendon showed both to be intact.

Dreyer [123] reports two satisfactory end-results of three years' duration following his operation for recurrent dislocation of the patella. He makes a longitudinal incision along the external border of the patella, and the iliotibial band and the insertion of the vastus externus into the patella are exposed. The insertion of the vastus externus into the patella is separated from the rest of the muscle and a flap is formed by continuing the incision about 8 cm. above the patella. This fascial flap still attached to the external border of the patella is divided above, passed beneath the rectus tendon, and fastened to the vastus internus which, when it contracts, pulls the patella inward. A capsulorrhaphy of the mesial capsule is also performed.

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120. McClure: Northwest Med. **21**:70 (March) 1921.

121. Gibson, A.: Dislocation of Sacro-Iliac Joint, J. A. M. A. **76**:1487 (May 28) 1921.

122. Rutherfurd: Brit. J. Surg. **8**:524 (April) 1921.

123. Dreyer: Deutsch. med. Wchnschr. **46**:489 (April 29) 1920.

FRACTURES

Spontaneous Fractures in the Young.—Hass [124] has encountered five cases of spontaneous fracture or infractions of the upper metaphysis of the tibia in boys ranging from 15 to 17 years of age. There were no signs of rickets or osteomalacia, and the roentgenograms revealed apparently normal bones. There was gradual onset of pain, increased by weight bearing. Bow leg deformity and shortening ensued. Union was very slow. He attributes the lesion to some nutritional disturbance.

Fracture Services.—Ollerenshaw [125] makes a strong plea for the establishment of special fracture services in general hospitals in charge of surgeons especially interested in bone and joint lesions. The importance of the inclusion of the outpatient cases in such a service is emphasized. He considers about 6 per cent. of the total number of hospital beds necessary for such a service, and he is convinced that such a plan will avoid many of the bad results which now occur from the general treatment of fractures.

Open Reductions.—Enloe [126] has been employing a rather unusual method in open reduction of fractures. A plaster cast is applied to the limb a week before the open reduction is to be attempted and the operation is performed through an ample window cut in the cast. He considers some of the advantages to be the ease of reduction during operation, the cast providing a fulcrum for leverage. Postoperative comfort and rest are assured. He reports no infections.

[ED. NOTE.—We can conceive of a very limited range of usefulness for this procedure; but our experience has been that the surgeon rarely knows before operation the exact position which is certain to hold the replaced fragments most securely in apposition. This judgment must be formed at the time of operation. If the position previously determined and maintained by a cast should not prove suitable to best retain the alinement, the removal of the cast in the presence of the open wound would be difficult without jeopardizing aseptic technic.]

Fracture of the Cervical Vertebrae with Cord Injury.—Osnato [127] reviews the operative mortality of four different surgeons of wide experience in cases of fracture of the cervical vertebrae with cord injury. He finds that this mortality ranges from 64 to 85 per cent. He reports four cases of his own treated conservatively, with only one death and three good recoveries. He urges nonoperative methods of treatment.

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124. Hass: Wien. klin. Wchnschr., 1919; abstr. Ztschr. f. orthop. Chir **41**: 366, 1921.

125. Ollerenshaw: Brit. M. J. **1**:559 (April 16) 1921.

126. Enloe: California State J. M. **19**:199 (May) 1921.

127. Osnato M. L.: Nonoperative Treatment of Fractures of the Cervical Vertebrae with Cord Injury, J. A. M. A. **76**:1737 (June 18) 1921.

Fractures of the Elbow in Children.—Stone [128] gives definite rules for treatment of some of the more common fractures of the elbow in children. In transverse supracondylar fracture, reduction should be attempted with the elbow fully extended or hyperextended. Traction should be exerted on the supinated forearm and the fragment reduced by rocking the arm, alternately, to the radial and to the ulnar side. Next, the elbow should be fully flexed under traction, and if no block occurs, reduction is usually satisfactory. This full flexion with the hand half way between supination and pronation is maintained for two weeks, and then a right angle splint is applied. After two weeks it is difficult to reduce this fracture without open operation. Stone emphasizes the fact that failure to regain full extension is often due to muscle spasm induced by too early use or too many attempts at passive motion. Further rest will cause the spasm to disappear and motion to return. Considerable degrees of deformity will in children often afford a functionally good result. Stone believes that operation is demanded in those cases in which the epiphysis of the external condyle has been detached and has "turned turtle." This operation yields good results up to six weeks after the injury. The roentgen-ray examination is often negative. In general, Stone says that the more skilled a surgeon becomes in closed reduction, the less often he will operate.

Forearm Fractures.—Seitz [129] points out the well known fact that the insertion of the pronator radii teres exerts a very definite influence on the position in which radial fractures should be immobilized. If the fracture is in the upper third above the insertion, the upper third is uncontrolled and supinates; therefore, the arm should be fixed in full supination. In fractures below the insertion, the opposite obtains, because the upper fragment is pronated by the action of the muscle. Therefore, the arm should be fixed in semipronation.

Grossman [130] has reviewed 200 cases of fracture of the forearm in children at the orthopedic clinic of the Lebanon Hospital. In only one of these cases was there a typical Colles' fracture and in 6.5 per cent. there was separation of the epiphysis. Twenty per cent. of the patients were below 5 years of age; 47 per cent. between 6 and 10; 31.5 per cent. from 11 to 13. Fracture of both bones was more common between 6 and 10, of one single bone more common between 11 and 13, and there was an equal number of fractures of single and double bones in the patients below 5 years of age.

Meyerding [131] reports fifty-nine cases of delayed union or nonunion of the radius and ulna treated at the Mayo Clinic. He has found the massive graft from the tibia fixed with bone screws to

128. Stone: J. Orthop. Surg. **3**:395 (Aug.) 1921.
129. Seitz: München. med. Wchnschr. **68**:425 (April 8) 1921.
130. Grossman: J. Orthop. Surg. **3**:217 (May) 1921.
131. Meyerding: Minnesota Med. **4**:223 (April) 1921.

yield the most satisfactory result. In the series reported, metal plates were employed in six cases and bone grafts in thirty-one. Thirty-four results have been tabulated, with good union in twenty-five, failures in seven, and improvement in two.

[ED. NOTE.—We note with interest Meyerding's championing of the massive graft in nonunion of the radius and ulna. It has been the experience of Chutro, Leriche, and others that, especially in these forearm bones, the thin osteoperiosteal transplant has best served the purpose, stimulating osteogenesis, and at the same time has easily nourished itself. The report of several observers has been that large grafts inserted in this region seem prone to late absorption or fracture.]

Fractures of the Carpal Scaphoid.—Todd,[132] in a valuable article, discusses fractures of the carpal scaphoid. He shows that the symptoms are characteristic and that the well marked symptoms and signs should make early diagnosis almost always possible. On early diagnosis depends the successful treatment of these fractures and probably also the chances of obtaining union. Todd pleads for prolonged fixation, three or four weeks, in a long "cock up" splint, holding the hand and fingers in dorsal flexion, with preservation of the carpal arch. A more or less permanently crippled wrist may be expected if treatment is not instituted early; and Todd points out that in the important series of cases reported by Codman and Chase [133] the only two cases which obtained union were those which were early immobilized for a long period. In old unrecognized cases with fibrous union or displacement, removal of one of the fragments has frequently greatly benefited the condition, the result sometimes amounting to an almost perfect functional recovery.

Fractures of the Femur.—Murphy and Dorrance [134] are enthusiastic over the results obtained by the abduction plaster-of-Paris spica treatment of intracapsular fractures of the neck of the femur. Eighteen of their twenty patients were between 60 and 80 years old. The ease of handling and the relief of pain was often very striking. There were two deaths, one patient being admitted in an unconscious condition. The two patients under 50 obtained bony union; the others showed firm fibrous union in the roentgenograms. Nine patients obtained full function; eight have only slight impairment of function; five use a cane; but all are capable of walking about.

Royal and Armitage Whitman [135] describe Royal Whitman's so-called reconstruction operation for ununited fracture of the neck

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132. Todd: Brit. J. S. **9**:7 (July) 1921.

133. Codman and Chase: Ann. Surg. **41**:321 (March) 1905.

134. Murphy and Dorrance: Ann. Surg. **73**:752 (June) 1921.

135. Whitman: Surg., Gynec. & Obst. **32**:479 (June) 1921; End-Results of Reconstruction for Ununited Fracture of Neck of Femur, J. A. M. A. **77**:913 (Sept. 17) 1921.

of the femur. The incision is vertical, beginning 1½ inches (3.8 cm.) posterior to the posterior superior spine of the ilium, extending downward to below the level of the trochanter and then backward, horizontally across the shaft. The fibers of the gluteus medius and of the tensor fasciae femoris are separated and the capsule is exposed and opened. The head of the femur is removed. Following the upper border of the gluteus minimus muscle, the base of the trochanter is reached and the trochanter with its attached muscles is chiseled off in a direction outward, downward, and slightly backward, so that the bone surface left by its removal corresponds to the inclination of the surviving portion of the neck. The outer surface of the shaft is then denuded of cortical bone, the neck placed in the acetabulum, the limb abducted, and the trochanter approximated to the shaft and fastened with kangaroo tendon, nail, graft, or peg. The plaster is left on six weeks. It is then removed and the patient is encouraged in the use of active and passive motion. When a fair degree of voluntary control has been established, the patient may get up. The first operation was performed Oct. 10, 1916. It has since been performed on nine other patients and there has been one death (embolism). All of the patients are free from pain and can bear weight on the hip. The amount of function varies. The operation is particularly applicable to old people, who have poor osteogenetic power, because it does not depend for success on the powers of bone union of the patient. It is also applicable in disease of the acetabulum. The pegging operation is not applicable when there is absorption of the neck, Whitman believes. "The Brackett operation is more difficult technically, union may not be obtained, and function is limited."

[ED. NOTE.—We see little difference in the technical difficulties of the Brackett and the Whitman operations. Whitman's point in relation to the osteogenetic powers of the patient may be well taken in older and more feeble subjects. Brackett's operation, which, briefly, consists of removing the trochanter and the remains of the neck and placing the rounded upper femoral end in the freshly prepared cuplike capital fragment, and transplanting the trochanter with its muscles attached lower down on the femoral shaft, while the position is maintained in abduction, seems to offer the more perfect anatomic result. The clinical results as we have seen them seem entirely to justify the anatomic expectation.]

Eikenbary [136] reports three cases of avulsion fracture of the lesser trochanter occurring at the adolescent period. He believes they fall into the class of lesions to which the partial avulsions of the tibial tubercle and the apophysitis of the os calcis belong. The powerful iliopsoas is attached to an epiphysis which begins to develop its center of ossifica-

136. Eikenbary: J. Orthop. Surg. **3**:464 (Sept.) 1921.

tion about the fourteenth year. A powerful contraction of this muscle might be expected partially to separate this growing center. Quite severe injury had occurred in all of Eikenbary's cases. There was a tendency toward flexion, resistance to extreme extension, pain on pressure over the region of the lesser trochanter, a decided limp, and a lordosis. The treatment consisted of anesthetization, and correction of the deformity by applying a plaster spica in full extension for six weeks. He reports complete recovery in all three cases.

Fracture of the Femoral Diaphysis Under Twelve Years.—Speed [137] has been impressed with the excellent functional results in the sixty-seven cases he has examined, regardless of the special method of treatment employed. Direct overhead traction he considers most useful up to 3 years of age and Thomas splints with overhead suspension of the splint and continuous traction in older cases. Caliper or pin traction was employed in a few cases.

Results of Fracture of Shaft of Femur.—Eliason [138] advocates direct overhead traction in fracture of the femoral shaft up to 8 years of age. Impressed with the unsatisfactory primary reductions in patients over 10 and with the uncertain results of even internal fixation when the limb is fixed with the thigh in extension, Eliason has come to believe that open operation and metal plate and screw fixation, with temporary wound drainage and immobilization in plaster and traction and thigh flexion, is the best method. He reports 90 per cent. of perfect results and 10 per cent. of good results from these procedures. The basis of his report is a study of 115 cases from the University of Pennsylvania Hospital.

[ED. NOTE.—We shall be surprised if many surgeons find it necessary to adopt Eliason's rather radical procedures as a routine in fractures of the femoral shaft. There is a generally expressed satisfaction with the results of skeletal traction combined with the Thomas splint after the method of Pearson, and our own observations are in accord with this expression. Metal plates and nonabsorbable material probably have a field of usefulness, but the field seems to be growing smaller as the technic of other, and as it seems to us more rational, methods becomes standardized. Complete access to the seat of fracture, the avoidance of open operation, and the escape from the use of nonabsorbable material surely make treatment safer and simpler.]

Fracture of the Spine of the Tibia.—Kurlander [139] has found only three cases of fracture of the spine of the tibia in 1,000 fractures. The mechanism of the injury he believes to be either violent hyperextension

137. Speed: Surg., Gynec. & Obst. **32**:527 (June) 1921.

138. Eliason: Ann. Surg. **74**:206 (Aug.) 1921.

139. Kurlander, J. J.: Fracture of Spine of Tibia, J. A. M. A. **77**:855 (Sept. 10) 1921.

of the knee or violence applied while the knee is flexed, abducted, and usually externally rotated. There is sudden severe pain, swelling, and blocking of extension. The differential diagnosis from lesions of the semilunar cartilages can only be certainly made by roentgenograms. He advises for treatment manipulation until complete extension is obtained, followed by immobilization in plaster for six weeks. If full extension is blocked and cannot be obtained by manipulation, open operation by means of the midpatella splitting approach is advised, with the removal of the offending fragment. If there is evidence of rupture of the crucial ligaments, immobilization should be continued for three months.

Fracture of the Os Calcis.—Straus [140] estimates that fractures of the os calcis represent about 2 per cent. of all fractures. The chief deformities consist of (1) the upward displacement of the posterior fragment of the os calcis where it is held by the pull of the Achilles tendon; (2) the obliteration of the longitudinal arch of the foot resulting in traumatic flatfoot. Any treatment to succeed must overcome these two conditions. Under ether anesthesia, Straus first tenotomizes the Achilles tendon and introduces a pin (unscrewing in the middle) over the top of the posterior fragment in front of the tendon. Traction is then exerted downward on the pin, which pulls the posterior fragment into position. A plaster cast is then applied while traction is still in force and any lateral displacement molded into position. At the same time the fore foot is pressed downward to restore the longitudinal arch and after the plaster is set the pin is unscrewed and pulled out from either side.

[Ed. Note.—The Editors consider the method well conceived and have found it satisfactory in application.]

Fractures of the Metatarsal Bones.—Alexander [141] calls attention to the very crippling character of fractures of the metatarsal bones unless accurate alinement and reduction of the frequently associated dislocations can be secured. He believes such accurate readjustment cannot in the majority of cases be obtained without open operation; and he urges the procedure as a routine in all of the common severe traumas which usually produce these injuries. The restoration of the normal arc, especially of the second and third metatarsal shafts, is of great importance if painful flatfoot is to be avoided.

Infraction of the Second Metatarsal Head.—Painter [142] reports the operative findings in three cases of this rather peculiar condition, well

140. Straus, D. C.: New Method of Treating Recent Fracture of the Os Calcis, J. A. M. A. **77**:176 (July 16) 1921.

141. Alexander: Ann. Surg. **74**:214 (Aug.) 1921.

142. Painter: Boston M. & S. J. **184**:533 (May 26) 1921.

described by Freiberg,[143] and consisting of pain referred to this point following sometimes a trivial injury and a subsequent quite marked flattening of the head, as revealed by the roentgenogram. All of Painter's cases were caused by stubbing the toe. One showed a thin sliver of cartilage separated from the head; the second showed a fracture extending part way into the epiphysis and including nearly the whole cartilage. These two were fairly recent cases. The third was of three years' duration; and at operation a loose ossicle, the size of a pea, was found between the flattened articular surfaces of the phalanx and the metatarsal. The metatarsal head had almost no cartilage on it and the phalangeal end was spiculated. The injury and the more or less characteristic later changes are probably much more common than is generally appreciated.

INDUSTRIAL SURGERY

Industrial Fractures.—Bassin[144] has reviewed the end-results of 442 fractures caused by industrial accidents. He compares these to the injuries of the war, stating that from 75 per cent. to 85 per cent. of the returning surgical cases in the Canadian Army and 65 per cent. in the American Army required further orthopedic and reconstructive surgery. Of the first thousand cases of industrial accidents presented before the workman's compensation courts, 76.3 per cent. required further treatment, though they supposedly represented end-results and 442 of these cases were end-results of fractures. The poorest results were those of simple fractures about the wrist and ankle. There had been also great lack of persistent traction on the fingers and toes, misinterpretation of roentgenograms in carpal and tarsal fractures, lack of immobilization, and too little physiotherapeutic after-treatment.

[ED. NOTE.—These are startling facts and figures and we fear quite true. They are exactly in line with the following review of the problems of traumatic surgery by an able industrial surgeon of wide experience during the war and in civil practice.]

Morehead[145] makes a plea for standardization of treatment in various types of traumatic surgery and illustrates his own practice. For example, in wounds of the soft parts he follows the final regulation war method, namely, débridement, primary or delayed primary suture, or chemical sterilization and secondary suture. In burns he first sterilizes with iodin and then employs moist dressings of sodium bicarbonate. When they begin to cicatrize he treats them with sunlight or electric light radiation. In dealing with the question of fractures, Morehead says the two important considerations are reduction and function.

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143. Freiberg: Surg., Gynec. & Obst. **19**:191 (Aug.) 1914.

144. Bassin: J. M. Soc. New Jersey **18**:115 (April) 1921.

145. Morehead, J. J.: Traumatic Surgery Problems, J. A. M. A. **76**:1642 (June 11) 1921.

Sixty per cent. consideration should be given to function and 20 per cent. each to union and contour. He employs skeletal traction whenever it is possible in the lower limb.

Osgood,[146] writing on the standardization of methods of treatment in orthopedic surgery and industrial surgery of the extremities and spinal column, has attempted to outline the methods now generally accepted, with special reference to early return of function and wage earning capacity. The article is sketchy but strives to be suggestive.

Eloesser[147] has been studying the problem of the severely, but not totally, disabled patient with special reference to the loss of an arm. Compensation, he believes, should be based on both the physical impairment of the injury and the previous occupation. All severely injured patients should be given the opportunity for vocational training and the new career should be based on the patient's previous knowledge and experience. Its continuation should depend on his intelligence and fitness. Only progress made warrants this. Agricultural laborers should be offered compensation in land and not in money.

RESEARCH

Development of Tendons.—Faldino[148] has made a very careful study of the development of tendons and arrives at the following conclusions: (1) The tendons and the synovial tendon sheaths are developed through various histologic modifications from a cellular cord which originally is differentiated from the mesenchyme which constitutes the original form of the extremities. (2) The original differentiation of the tendons occurs at two distinct points—one proximal, in connection with the muscle tissue, the other distal, in connection with the movable skeletal segment. (3) All the tendons do not appear at the same epoch. The tendons develop first where function is most necessary for the life of the embryo, thus the flexor tendons of the hands and feet develop first. (4) In human embryos of 18 mm. these tendons are outlined and there exists at this stage of development the early form of the tendon sheath. (5) The primitive form of the extensor tendons of the digits of the hand and foot are found in sections of the wrist and ankle in embryos of 25 mm. and not before. (6) The synovial sheath of the tendon must be considered as the matrix of the tendon, since at the time of its differentiation the tendon is seen to take its origin from the inner layer of the synovia. (7) In the early stages of development, the tendons are all placed in one layer. The deep tendons of the muscles of the same name and function are differentiated much later. (8) The tendons of the common superficial flexor

146. Osgood: Illinois M. J. **39**:342 (April) 1921.
147. Eloesser: Boston M. & S. J. **184**:489 (May 12) 1921.
148. Faldino: Chir. d. org. di movimento **5**:43 (Feb.) 1921.

muscles of the digits and the common superficial extensor muscles of the digits are formed from the already differentiated homologous muscles. (9) In the case of muscles having multiple tendons, these are formed from an original single connective tissue segment. (10) The endothelial layer that covers the inner surface of the synovia constitutes, previous to the entire detachment of the tendon, the endothelial covering of the tendon itself. (11) The development of the tendons, thus differentiated, can be said to be complete after the fifth month. Tendons that are free in the synovia can be found, nevertheless, earlier in embryos of 130 mm. (12) The nutrition of the tendon is derived from the synovial sheath. (13) On the tendon sheaths of very early embryos (from 35 to 75 mm.) can be observed a great quantity of blood vessels, some of which pass into the tendon tissue itself. These vessels become smaller with the progress of the development and finaly disappear in the greater part of the sheaths. (14) In the first stages of development and up to the fourth month, the tendon sheath is noticeably thick in comparison with the contained tendon, which is very small. (15) Synovial cavities are found only after a considerable degree of differentiation (25 mm.). (16) The origin of the synovial cavities is independent of activity. (17) Bursae in connection with tendons are found in human embryos of 41 mm. as little cushions, which at this stage are without demonstrable cavities which only appear later.

Repair of Injury of Joint Cartilages.—Ciociola,[149] on account of the discordant reports in the literature regarding the repair of cartilage wounds, undertook a series of experiments on eleven dogs, using the cartilage of the femorotibial joint. The animals were kept alive from two to sixty days. From a very careful microscopic study of the tissues removed, he arrived at the following conclusions: (1) Wounds of the articular cartilage involving the underlying bony layers, as such wounds occasionally do, are healed through activity of the bone tissues, giving rise to a young connective tissue. (2) This tissue of repair, after a certain time, presents indications of transformation into hyaline cartilage. (3) Superficial wounds made in a tangential direction and which do not pass through the thin hyaline cartilage show no reaction even after two months and remain as small wounds.

Ossification Centers of Wrist, Knee, and Ankle at Birth.—Adair and Scammon [150] have found the inferior femoral epiphysis to be present in 98 per cent. of all new-born children, the superior tibial epiphysis in 81 per cent., the cuboid in about 60 per cent., and two carpal centers, the os capitatum (os magnum) and os hamatum (unciform), occasionally present. There is a close relation between total body length and the presence of the centers at birth.

149. Ciociola: Policlinico **28**:229 (June 15) 1921.
150. Adair and Scammon: Am. J. Obst. & Gynec. **2**:35 (July) 1921.

Epiphyses at the Elbow.—Cohn [151] believes that there are four centers of ossification of the lower end of the humerus: (1) the capitellum, which is first to appear and is alone present up to 5 years; (2) the internal epicondyle, which appears next; (3) the trochlea, and (4) the external epicondyle, occasionally. At 14 years of age, these centers have all joined the shaft except the internal epicondyle, which may remain ununited even at the age of 17.

Bone Atrophy.—Allison [152] has made an experimental study of the phenomena of bone atrophy. In these experiments, in which nonuse was produced by nerve paralysis, injury to joints, and simple fixation, the changes observed in the bone were the same. The degree of atrophy of the bone was directly proportional to the degree of nonuse, regardless of the method used to produce the nonuse. Simple fixation produced as rapidly developing and as marked bone atrophy as nonuse due to section of nerves or injury to joints. Complete fixation of a dog's extremity is so difficult that this method was not extensively employed. There is no evidence warranting the assumption that any disease process plays any rôle in the production of bone atrophy other than its effect on use. That bone atrophy is not the result of diminished circulation of blood is shown by the fact that bone atrophy rapidly develops in the acute inflammatory diseases which limit the function of an extremity. They have also observed a patient in whom the popliteal artery was ligated and in whom there was a diminution of blood supply to the leg sufficient to cause a complete ischemic paralysis and a slowly developing gangrene, yet the tibia showed no evident atrophy after a period of four months. Bone absorption is an active process and the circulation of the blood is necessary to its progress. The process of bone atrophy is not a change in the characteristics of bone as a tissue. The process of bone atrophy is a change in the amount of bone present. This affects the size, shape, thickness, length, weight, and texture of the whole bone and accounts for its changes in gross anatomy, roentgenograms, breaking strength, and chemical composition. The chemical composition, breaking strength, and regeneration of bone remain unchanged.

MISCELLANEOUS

Giant Cell Tumor of the Knee Joint.—Blanco [153] adds another case of a giant cell tumor of the xanthic type to the seventeen reported from the Mayo Clinic. Blanco removed this tumor from the capsule of the knee joint and found it to be intimately connected with the infrapatellar fat pad. These tumors are benign and are considered as

151. Cohn, Isidore: Observations on the Normally Developing Elbow, Arch. Surg. **2**:455 (May) 1921.

152. Allison and Brooks: Surg., Gynec. & Obst. **33**:250 (Sept.) 1921.

153. Blanco: J. Orthop. Surg. **3**:156 (April) 1921.

a type of granulation tissue resulting from hemorrhage. They are usually located on the extremities and are commonly associated with a tendon or its sheath. To the author's knowledge their presence in the joints has not been hitherto reported.

Kondoléon Operation for Elephantiasis.—Henry [154] and Green [155] have both discussed the Kondoléon operation and report distinct benefit from it in cases of elephantiasis. Lanz, in 1911, first recognized that the deep fascia was a barrier to lymph absorption and Kondoléon of Athens, as a result of operation and experiment, concluded that small slits in the deep fascia were inadequate for deep drainage. Kondoléon, therefore, in 1912, devised the operation which bears his name. His basic idea is to remove sufficient strips of fascia lata to produce a series of wide muscle hernias, as it were. The alternate bulging and withdrawal serves to aspirate the fluid from the subcutaneous tissue into the muscle strata. Scar tissue naturally forms in the gaps; but anastomosing lymphatics and veins also form. In the operation performed by Green, two long wedge shaped strips of skin, subcutaneous fat, and fascia lata were excised from the lateral and mesial aspects of the thigh from the level of the trochanter and just below the perineum to the malleoli. The tissue removed weighed 6 pounds (2.7 kg.). The operation was followed by some shock. Elastic bandages were applied and in a week softening was noted and ultimate recovery was complete. Kondoléon reported eight successful cases and seventeen others have been reported with improvement. Green is certain that filariasis is more common in the southern United States than is supposed. Johnson found 19 per cent. in 400 persons examined. Probably not over 5 per cent. of the persons infected develop elephantiasis. Nearly all of them have attacks of erysipelas. The pathologic changes in elephantiasis are: (1) mechanical obstruction of the veins and lymphatics from a progressive lymphangitis; (2) hyperplasia of the collagenous connective tissue of the hypoderm; (3) gradual disappearance of the elastic fibers of the skin; (4) the presence of a coagulable dropsy; (5) a chronic reticular lymphangitis caused by the secondary repeated invasion of micro-organisms.

Orthostatic Albuminuria.—An Editorial in the *Journal of the American Medical Association* [156] outlines the theories of etiology of the intermittent albuminurias associated with the faulty posture of exaggerated lumbar lordosis. The explanation has been offered by Jehle that this position of the spine causes in the erect position a mechanical interference with renal function. The arrangement of the renal veins

154. Henry, A. H.: Brit. J. Surg. **9**:111 (July) 1921.

155. Green: Virginia M. Monthly **48**:196 (July) 1921.

156. An Explanation of Orthostatic Albuminuria, Editorial, J. A. M. A. **77**:127 (July 9) 1921.

varies on the two sides, and Sonne of Copenhagen has seemed to prove the correctness of Jehle's explanation by finding in six cases of typical orthostatic albuminuria by ureteral catheterization albuminous urine from the left kidney alone. This is in harmony with the belief that the abnormally lordotic spine in the upright position may cause compression of the left renal vein.

Care of Crippled Children.—Girdlestone [157] estimates that England and Wales need 10,000 beds for the care of crippled children and that the expenditure necessary to provide for these and for the education of these children would be entirely justified by the economic results. In the city of Birmingham, for example, out of 1,001 cripples only 111 were self-supporting. He believes with proper hospital treatment 90 per cent. can be made wage-earning. The great groups include congenital deformities, paralytic deformities, and those following tuberculous bone and joint disease. Nearly all these deformities are preventable and correctable. Girdlestone advocates a central committee to take the matter in hand.

[ED. NOTE.—Girdlestone is surely right in voicing this economic and humanitarian demand. This great need has been recognized in America by the Order of the Mystic Shrine, which by an equal annual assessment on its entire membership is placing in the hands of its trustees for the Shriners Hospitals for Crippled Children more than a million dollars a year. Hospitals are being built in different parts of this country and Canada, and an advisory board of orthopedic surgeons has been requested to nominate the chief surgeons of these hospitals and to make suggestions as to their conduct. They are to be teaching hospitals so far as possible, and they are to receive only needy patients up to 14 years of age, irrespective of race or religion. The movement is continental in its scope and should yield far-reaching results. This great annual fund becomes a light burden when divided equally and placed on many strong shoulders.]

The Teaching of Orthopedic Surgery.—A most valuable and onlooking article on this subject has been written by Allison.[158] He believes that so-called orthopedic surgery differs in none of its principles from so-called general surgery. He suggests that orthopedic surgery should not be taught to undergraduates as orthopedic surgery, but that the orthopedic surgeon teach them certain phases and problems of surgery. To the question, What is orthopedic surgery? Allison answers, "The surgery of the extremities and spinal column, which has the reestablishment of function as its guiding principle." He believes that the didactic lecture ought to be less and less used

157. Girdlestone: Brit. M. J. **1**:697 (May 22) 1920; Lancet **1**:74 (Jan. 8) 1921.

158. Allison: J. Orthop. Surg. **3**:448 (Sept.) 1921.

and that demonstrations ought to be demonstrations of some principle, and not of the skill of the operator. The student must be taught how to develop proper thinking. He considers the properly conducted clinical conference of great value both to the student and to the teacher.

[ED. NOTE.—We find ourselves in essential accord with Allison's point of view. As he says, the part cannot be greater than the whole. Orthopedic surgeons must train themselves to the highest points of surgical skill and judgment, in closest contact with general surgery, seeking to contribute to its needs, and happiest when its methods become the property and the practice of the general surgeon and the internist. Unless the specialty thus seeks closest contact, giving and taking, its field of usefulness will be small and its labor dull.]

BOOK REVIEW

INJURIES AND DISEASES OF THE BONES AND JOINTS: THEIR DIFFERENTIAL DIAGNOSIS BY MEANS OF THE ROENTGEN RAY. By FREDERICK H. BAETJER and CHARLES A. WATERS. Cloth. Price, $10.00 net. Pp. 349, with 333 illustrations. New York: Paul B. Hoeber, 1921.

This book may be best described as an atlas of roentgenograms of various bone and joint conditions with accompanying text describing the pathologic, clinical and roentgenologic findings. It is handsomely published in royal octavo of 349 pages, with 333 large, clear illustrations. An idea of its scope may be gained from the following tabulation of the contents. Normal bone and epiphyses, thirty-three pages; fractures, 100 pages; dislocations, congenital and acquired, twenty-six pages; bone infections, twenty-four pages; joint lesions, fifty-eight pages; bone tumors, forty-eight pages; spine, twenty-two pages; abnormalities, twelve pages; dystrophies, ten pages. The chapters on bone tumors and joint lesions are excellent; those on the epiphyses, bone repair, nonunion and bone grafting might perhaps be amplified. There is little mention made of variations in normal anatomy, particularly that of the spine. The authors have compiled a very excellent book and one that fills a long felt need of the general practitioner, the general surgeon, and the medical student.

INDEX TO VOLUME 4

Ankle, classification and mechanism of fractures of leg bones involving ankle, based on a study of 300 cases from Episcopal Hospital; A. P. C. Ashhurst and R. S. Bromer..... 51

Apfelbach, C. W.: Studies in traumatic fractures of cranial bones: I. Edema of brain. II. Bruises of brain..... 434

Ashhurst, A. P. C.: Classification and mechanism of fractures of leg bones involving ankle, based on a study of 300 cases from Episcopal Hospital 51

Barney, E. L.: A detailed bacteriologic study of a case of gas gangrene following a compound fracture; studies on pathogenic anaerobes.. 470

Barron, M.: Carcinoma of lung: a study of its incidence, pathology and relative importance, with a report of 13 cases studied at necropsy.. 624

Behrend, M.: Comparative results of ligation of hepatic artery in animals; its application to man..... 661

Bladder, technic of treatment of carcinoma of bladder and prostate by a combination of surgery, electrocoagulation, radium implantation and roentgen ray; B. A. Thomas and G. E. Pfahler..... 451

Bone, sarcoma of, review and classification of; J. Ewing..... 485

Brain, edema of, studies in traumatic fractures of cranial bones. I. Edema of brain. II. Bruises of brain; C. W. Apfelbach..... 434

Breitstein, M. L.: Papilloma of larynx in children, report of 11 cases.... 275

Bromer, R. S.: Classification and mechanism of fractures of leg bones involving ankle, based on a study of 300 cases from Episcopal Hospital 51

Bursitis, radiohumeral bursitis, epicondylitis, epicondylalgia (tennis elbow), a personal experience; R. B. Osgood..... 420

Cannon, W. B.: Studies in experimental traumatic shock. V. Critical level in a falling blood pressure..... 300

Studies in experimental traumatic shock. IV. Evidence of a toxic factor in wound shock..... 1

Carcinoma of lung: a study of its incidence, pathology and relative importance, with a report of 13 cases studied at necropsy; M. Barron.... 624

Cattell, McK.: Studies in experimental traumatic shock. V. Critical level in a falling blood pressure..... 300

Chest wall, open pneumothorax in its relation to extirpation of tumors of bony chest wall; C. A. Hedblom..... 588

Cholecystitis, further observations on lymphatic origin of cholecystitis, choledochitis and associated pancreatitis; E. A. Graham and M. G. Peterman 23

Choledochitis, further observations on lymphatic origin of cholecystitis, choledochitis and associated pancreatitis; E. A. Graham and M. G. Peterman 23

Cranium, studies in traumatic fractures of cranial bones. I. Edema of brain. II. Bruises of brain; C. W. Apfelbach..... 434

Crile, G. W.: Studies in exhaustion. III. Emotion..... 130

Crowe, S. J.: Papilloma of larynx in children, report of 11 cases..... 275

Cutler, E. C.: Relaxed pelvic floor: end-result in 60 cases..... 175

Emotion, studies in exhaustion. III. Emotion; G. W. Crile..... 130

Ewing, J.: A review and classification of bone sarcomas..... 485

Exhaustion, studies in exhaustion. III. Emotion; G. W. Crile..... 130

Fractures, classification and mechanism of fractures of leg bones involving ankle, based on a study of 300 cases from Episcopal Hospital; A. P. C. Ashhurst and R. S. Bromer..... 51

Gangrene, a detailed bacteriologic study of a case of gas gangrene following a compound fracture: studies on pathogenic anaerobes, III; E. L. Barney and H. H. Heller..... 470

Graham, E. A.: Further observations on lymphatic origin of cholecystitis, choledochitis and associated pancreatitis..... 23

Harrison, P. W.: Inguinal hernia: a study of principles involved in surgical treatment 680

Hedblom, C. A.: Open pneumothorax in its relation to extirpation of tumors of bony chest wall..... 588

Heller, H. H.: A detailed bacteriologic study of a case of gas gangrene following a compound fracture; studies on pathogenic anaerobes.. 470

Hepatic artery, comparative results of ligation of hepatic artery in animals; its application to man; M. Behrend, H. E. Radasch and A. G. Kershner..... 661

Hernia, inguinal: study of principles involved in surgical treatment; P. W. Harrison..... 680

postoperative intra-abdominal hernia; G. H. Mayo and J. A. H. Magoun, Jr. 324

Hibbs, R. A.: Fracture-dislocation of spine treated by fusion..... 598

Hinman, F.: Structural results of prostatectomy with reference to methods of enucleation, based on a study of 136 cases..... 154

Intestinal obstruction, unusual case; A. M. Willis..... 690

Jackson, C.: Ventriculocardectomy, a new operation for cure of goitrous paralytic laryngeal stenosis..... 257

Jameson, C. H.: Relaxed pelvic floor: end-result in 60 cases..... 175

Kershner, A. G.: Comparative results of ligation of hepatic artery in animals; its application to man..... 661

Larynx, papilloma of larynx in children, report of 11 cases; S. J. Crowe and M. L. Breitstein..... 275

stenosis, ventriculocardectomy, a new operation for cure of goitrous paralytic laryngeal stenosis; C. Jackson..... 257

Lung, carcinoma of lung: a study of its incidence, pathology and relative importance, with a report of 13 cases studied at necropsy; M. Barron 624

Magoun, J. A. H., Jr.: Postoperative intra-abdominal hernia..... 324

Mayo, C. H.: Postoperative intra-abdominal hernia..... 324

Morton, J. J.: Generalized type of osteitis fibrosa cystica; von Recklinghausen's disease 534

Orthopedic surgery, seventeenth report of progress in orthopedic surgery; R. B. Osgood, R. Soutter, H. C. Low, M. S. Danforth, L. T. Brown and P. D. Wilson..... 693

sixteenth report of progress in orthopedic surgery; R. B. Osgood, R. Soutter, H. C. Low, M. S. Danforth, C. H. Bucholz, L. T. Brown and P. D. Wilson..... 200

Osgood, R. B.: Radiohumeral bursitis, epicondylitis, epicondylalgia (tennis elbow), a personal experience..... 420

and others: Seventeenth report of progress in orthopedic surgery..... 693

and others: Sixteenth report of progress in orthopedic surgery..... 200

Osteitis fibrosa cystica, generalized type of osteitis fibrosa cystica; von Recklinghausen's disease; J. J. Morton..... 534

Osteomyelitis, acute, hematogenous; C. L. Starr..... 567

Pancreatitis, further observations on lymphatic origin of cholecystitis, choledochitis and associated pancreatitis; E. A. Graham and M. G. Peterman 23

Papilloma of larynx in children, report of 11 cases; S. J. Crowe and M. L. Breitstein..... 275

Pelvic floor, relaxed pelvic floor: end-result in 60 cases; E. C. Cutler and C. H. Jameson..... 175

Peterman, M. G.: Further observations on lymphatic origin of cholecystitis, choledochitis and associated pancreatitis..... 23

Pfahler, G. E.: Technic of treatment of carcinoma of bladder and prostate by a combination of surgery, electrocoagulation, radium implantation and roentgen ray..... 451

Pneumothorax, open, in its relation to extirpation of tumors of bony chest wall; C. A. Hedblom..... 588

Prostate cancer, technic of treatment of carcinoma of bladder and prostate by a combination of surgery, electrocoagulation, radium implantation and roentgen ray; B. A. Thomas and G. E. Pfahler..... 451

Prostatectomy, structural results of prostatectomy with reference to methods of enucleation, based on a study of 136 cases; F. Hinman..... 154

Radasch, H. E.: Comparative results of ligation of hepatic artery in animals; its application to man..... 661

Recklinghausen's disease, generalized type of osteitis fibrosa cystica; von Recklinghausen's disease; J. J. Morton..... 534

Sarcoma, review and classification of bone sarcomas; J. Ewing..... 485

Seminal tract, radical cure of tuberculosis of seminal tract. I. Brief survey of literature; H. H. Young..... 334

Shock, studies in experimental traumatic shock. IV. Evidence of a toxic factor in wound shock; W. B. Cannon..... 1

studies in experimental traumatic shock. V. Critical level in a falling blood pressure; W. B. Cannon and McK. Cattell..... 300

Spine, fracture-dislocation of spine treated by fusion; R. A. Hibbs..... 598

Starr, C. L.: Acute hematogenous osteomyelitis..... 567

Tennis elbow (radiohumeral bursitis, epicondylitis, epicondylalgia), a personal experience; R. B. Osgood..... 420

Thomas, B. A.: Technic of treatment of carcinoma of bladder and prostate by a combination of surgery, electrocoagulation, radium implantation and roentgen ray..... 451

Tuberculosis, radical cure of tuberculosis of seminal tract: I. Brief survey of literature; H. H. Young..... 334

Ventriculocardectomy, a new operation for cure of goitrous paralytic laryngeal stenosis; C. Jackson..... 257

Willis, A. M.: Unusual case of intestinal obstruction..... 690

Young, H. H.: Radical cure of tuberculosis of seminal tract. I. Brief survey of literature..... 334

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CONTENTS

PAGE

A Review and Classification of Bone Sarcomas. James Ewing, M.D., New York 485

The Generalized Type of Osteitis Fibrosa Cystica: Von Recklinghausen's Disease. John J. Morton, M.D., New Haven, Conn 534

Acute Hematogenous Osteomyelitis. Clarence L. Starr, M.D., Toronto, Canada 567

Open Pneumothorax in Its Relation to the Extirpation of Tumors of the Bony Chest Wall. Carl A. Hedblom, M.D., Rochester, Minn 588

Fracture-Dislocation of the Spine Treated by Fusion. Russell A. Hibbs, M.D., New York 598

Carcinoma of the Lung: A Study of Its Incidence, Pathology and Relative Importance, with a Report of Thirteen Cases Studied at Necropsy. Moses Barron, M.D., Minneapolis 624

Comparative Results of the Ligation of the Hepatic Artery in Animals: Its Application to Man. Moses Behrend, M.D.: H. E. Radasch, M.D., Philadelphia, and Ammon G. Kershner, M.D., Norristown, Pa 661

Inguinal Hernia: A Study of the Principles Involved in the Surgical Treatment. P. W. Harrison, M.D., Bahrein, Persia 680

An Unusual Case of Intestinal Obstruction. A. Murat Willis, M.D., Richmond, Va 690

Seventeenth Report of Progress in Orthopedic Surgery. Robert B. Osgood, M.D.; Robert Soutter, M.D.; Harry C. Low, M.D.; Murray S. Danforth, M.D.; Lloyd T. Brown, M.D., and Philip D. Wilson, M.D., Boston 693

Index 749